SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

ANNUAL CONVENTION NUMBER

Special Features

Sludge Drying Bed Performance—Haseltine

Ultrasonics Research—Lyon

Palmer-Bowlus Flume Design—Ludwig and Ludwig

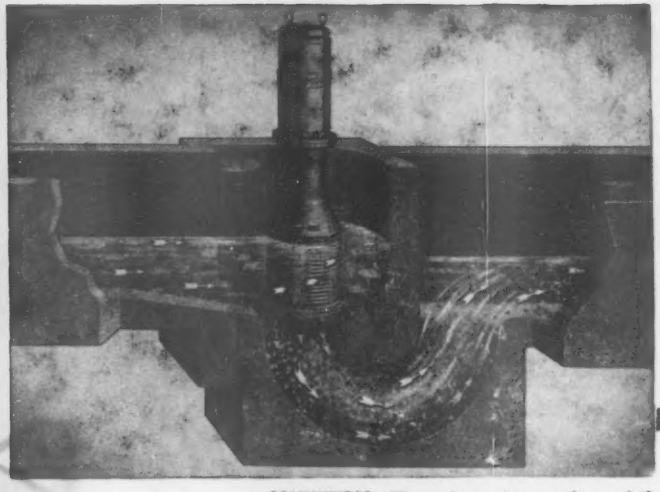
Industrial Wastes Color—Rudolfs and Hanlon

Bacterial Pollution Indices—Lattanzi and Mood

Twenty-Fourth Annual Meeting—Oct. 8–11, 1951
Municipal Auditorium, St. Paul, Minn.
(See Page 1204)

SEPTEMBER, 1951—VOL. 23, No. 9

CHICAGO SEWAGE EQUIPMENT



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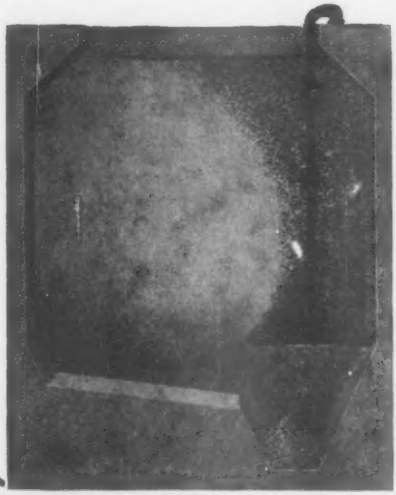
SCRU-PELLER SLUDGE PUMPS—The Scru-Peller Pump is specifically designed to handle sludge. Coarse, stringy material is cut and cannot wrap or bind the impeller.

CHICAGO 'PAKAGE' PLANT—Equipment specifically designed to provide Activated Sludge Sewage Treatment for small communities, institutions and industrial plants. Low initial and operating costs with minimum supervision required.

CHICAGO-WIGGINS PONTOON COVER—The Pontoon Cover always floats on liquid, never on gas, assuring positive scum submergence. Pontoon Cover cannot tip. Extra deep trusses provide maximum strength with minimum weight.

CHICAGO-WIGGINS GAS HOLDER—All moving parts are on the outside, away from contact with sludge. Balancing mechanism cannot jam or corrode, assuring instant and positive compensation of wind stress and snow load. The Gas Holder cannot tilt or leak



AER-DEGRITTER—The Chicago Aer-Degritter provides the only method of removing grit and sand from sewage without movable mechanical equipment in the tank.

CHICAGO-WIGGINS LODEK COVER—Specifically designed for large diameter sewage digesters. The Lodek Cover incorporates the latest techniques in design and construction.

CHICAGO NON-CLOG PUMPS—Chicago Vertical and Horizontal Non-Clog Pumps have been serving sewage treatment plants for over 40 years. Rugged, oversized shaft and bearings assure years of trouble-free service.

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There is Chicago Sewage Equipment specifically designed and engineered for every phase of treatment of Sewage and Industrial Wastes. Chicago Swing Diffusers and Precision Tubes for pre-aeration and channel aeration; the Tru-Test Sewage Sampler; the Odeeometer for D.O. determinations, Sludge Collectors and other Equipment for the treatment of Sewage and Industrial Wastes.

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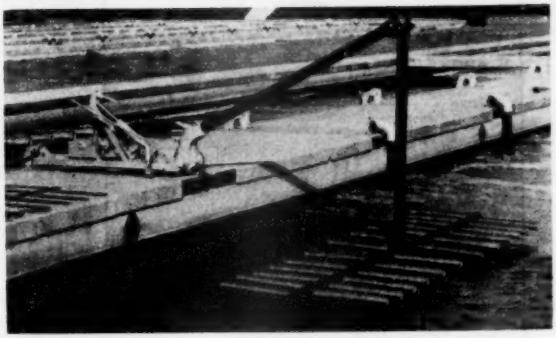

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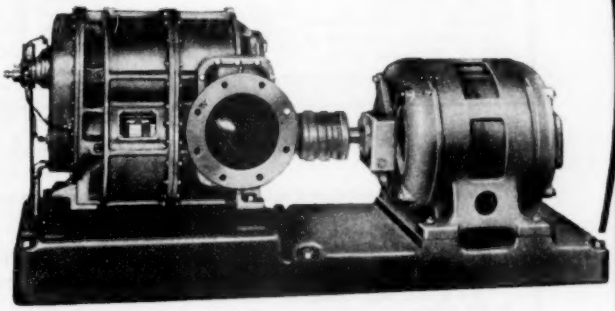

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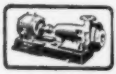

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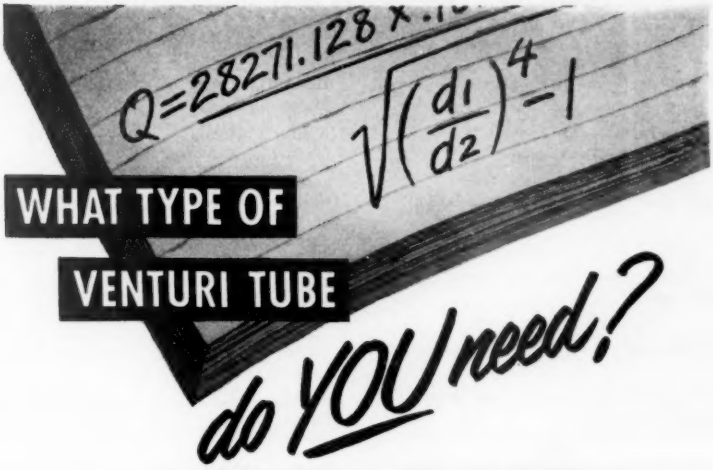

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2. Cast iron Venturi Tube with hand holes and cleaning valves at main and throat sections, for municipal sewage and trade wastes.

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Association	*Place*	*Time*
Iowa Sewage Works Association	Hotel Tall Corn, Marshalltown, Iowa	Sept. 11–13, 1951
Kentucky–Tennessee Industrial Wastes and Sewage Works Association	Kentucky Hotel, Louisville, Ky.	Sept. 17–19, 1951
Georgia Water and Sewage Association	Georgia Institute of Technology, Atlanta, Ga.	Sept. 19–21, 1951
South Dakota Water and Sewage Works Conference	Charles Gurney Hotel, Yankton, S. Dak.	Sept. 19–21, 1951
Rocky Mountain Sewage Works Association	Cosmopolitan Hotel, Denver, Colo.	Sept. 26, 1951
North Dakota Water and Sewage Works Conference	Gardner Hotel, Fargo, N. Dak.	Sept. 26–28, 1951
Missouri Water and Sewerage Conference	Robidoux Hotel, St. Joseph, Mo.	Sept. 30–Oct. 2, 1951
West Virginia Sewage and Industrial Wastes Association	Daniel Boone Hotel, Charleston, W. Va.	Oct. 3–4, 1951

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Florida Sewage and Industrial Wastes Association	Sheraton Plaza Hotel, Daytona Beach, Fla.	Oct. 28–31, 1951
New England Sewage Works Association	Sheraton-Biltmore Hotel, Providence, R. I.	Nov. 6–7, 1951
North Carolina Sewage and Industrial Wastes Association	Robert E. Lee Hotel, Winston-Salem, N. C.	Nov. 12–14, 1951
Oklahoma Water, Sewage and Industrial Waste Conference	Oklahoma A. & M., Stillwater, Okla.	Dec. 3–7, 1951
New York Sewage and Industrial Wastes Association	Hotel Statler, New York, N. Y.	Jan. 17–18, 1952
Texas Water and Sewage Works Association	Texas A. & M., College Station, Texas	March 9–13, 1952
Arkansas Water and Sewage Conference	Engineering Building, University of Arkansas, Fayetteville, Ark.	April 7–9, 1952

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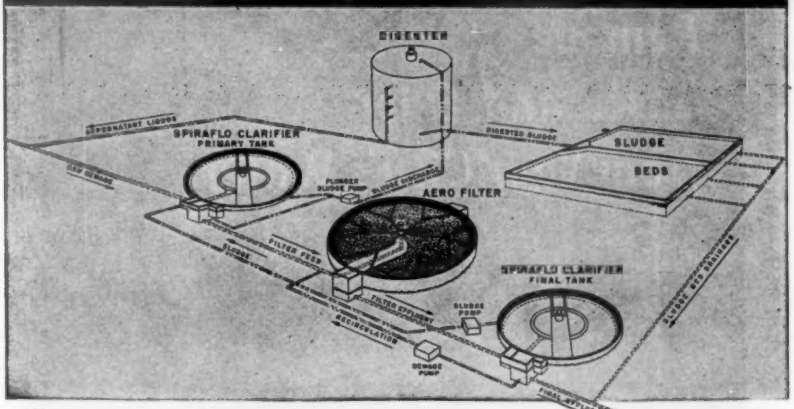

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These figures show a typical result produced by a Yeomans installation of the "Aero-Filter" and "Spiraflo" Clarifier in combination.

Overall plant efficiency is always higher when these units are used together. The method is especially effective for treating strong industrial wastes.

OPERATIONAL DATA . . . SPIRAFLO—AERO-FILTER PLANT *

1949 Date	Sewage Flow M.G.D.	Raw Sewage		Primary Effluent				Final Effluent				Overall Plant Reduction	
		Sus. Solids PPM	B.O.D. PPM	Sus. Solids PPM	Per Cent Reduction	B.O.D. PPM	Per Cent Reduction	Sus. Solids PPM	Per Cent Reduction	Per Cent PPM	Per Cent Reduction	Sus. Solids Per Cent	B.O.D. Per Cent
6-15	0.2996	210	255	79	62.4	136	46.6	28	64.6	18	86.8	86.6	93.0
6-16	0.2467	425	260	85	80.0	127	51.2	23	73.0	19	85.1	94.6	92.6
6-17	0.2554	410	235	124	69.7	141	40.0	28	77.4	18	87.3	93.3	92.4
6-18	0.2487	308	222	76	75.4	108	51.4	34	55.3	16	85.2	89.0	92.8
6-19	0.1753	222	218	64	71.2	132	39.5	17	73.5	—	—	92.4	—
6-20	0.2666	262	320	88	66.4	147	54.1	20	77.3	30	79.6	92.4	90.6
6-21	0.2279	240	215	78	67.5	138	35.8	19	75.7	20	85.7	92.0	90.7
Average	0.2456	297	247	85	70.5	132	45.5	24	71.0	20	85.0	91.5	92.0

* Name of plant furnished on request, as well as operating data from other installations.

"Spiraflo" Advantages

- Increased B.O.D. and settleable solids removal —influent is introduced tangentially into annular race around the periphery. Sewage spirals downward slowly and enters main clarification compartment at the bottom of the tank. Uniform, slow diffusion of waste under the skirt results in greatly reduced velocities and provides maximum removal of settleable solids.
- Greater removal of finely divided particles—due to upward flow through sludge blanket. This increases flocculation and results in more effective removal of finely divided particles before waste enters the effluent weirs.
- Straight-wall design minimizes construction costs.

"Aero-Filter" Advantages

- Thorough uniform distribution—therefore costly recirculation for dilution is unnecessary
- Operating cost is lowest of any type of complete sewage treatment
- Uninterrupted and almost complete momentary bed coverage minimizes troubles from odors, freezing, ponding, filter flies
- All returns made direct to the filter—no oversize primary tank required.

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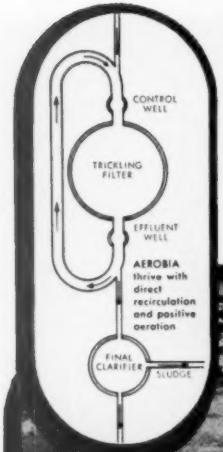
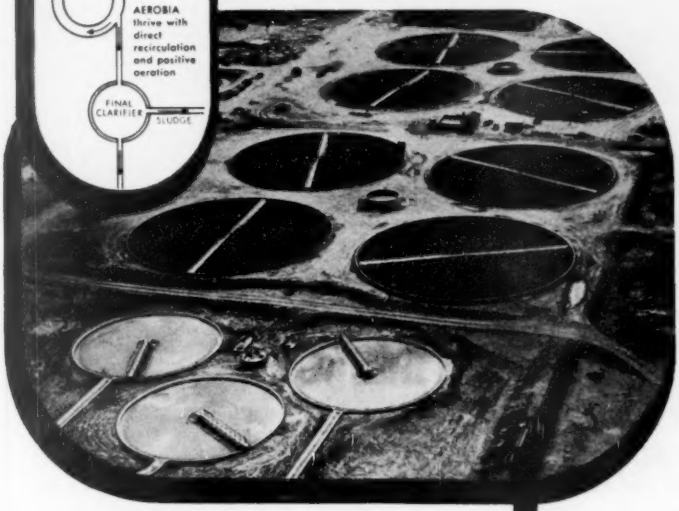


how Worcester, Mass., modernized 1925 Sewage Plant with an

Accelo® Filter *system*



To give Worcester a modern 20,000,000 g.p.d. treatment plant, consulting engineers replaced 1925 equipment with the Infilco Accelo Filter system with *direct recirculation* and *positive aeration.*

The system has 8 rotary distributors 176 ft. in diameter with aero-spray nozzles. Excellent distribution is obtained over filter surfaces with vigorous growth of bacterial gel. Three Infilco PD Clarifiers (foreground) provide effective final sludge removal.

Specify Infilco for:

- Increased Filter Efficiency
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- No Clogging, Sloughing Or Ponding
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Sewerage dollars cover more ground when you use Armco Corrugated Metal Structures.

There is a type and size for every need from 6-inch round pipe to 24-foot MULTI-PLATE Arch. Problems of erosion, corrosion and limited headroom are quickly solved. You save in handling and hauling because Armco Structures are light in weight and often can be nested to save space.

Installation is also economical. Long lengths of standard Armco Pipe mean fewer sections to lay, line and join. Simple band couplers assure speedy, positive connections. Precurved MULTI-PLATE sections are delivered, ready for quick field assembly. Jobs go fast with just a small crew. No special tools are required.

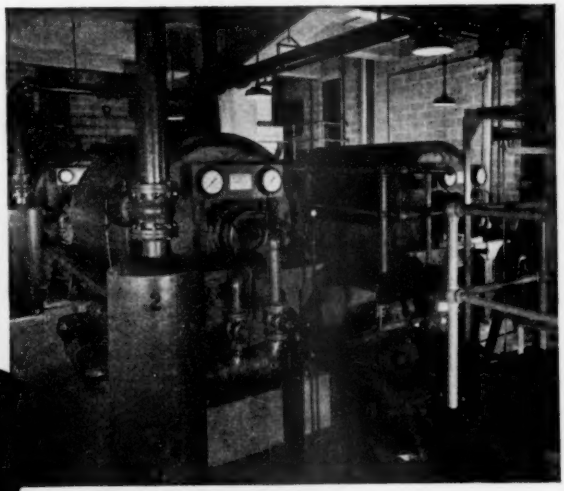
And here is something else. Nearly half a century of underground service proves the lasting economy of Armco Corrugated Metal Structures. They have ample strength and durability to serve for years with little or no maintenance. Let us show you how they save time and money. Call or write today. Armco Drainage & Metal Products, Inc., 2031 Curtis St., Middletown, O.

ARMCO SEWER STRUCTURES

ARMCO

See General American for

CREATIVE FILTER ENGINEERING



Designed to do your job best!

Section of the filter room showing Conkey Sludge Filters in recently opened Bridgeport primary treatment plant.

Newly completed Bridgeport, Conn., Sewage Treatment Plant uses Conkey Sludge Filters

Bridgeport's new East Side primary treatment plant handles a high percentage of diversified industrial wastes. Careful planning plus several unique innovations were required to successfully dewater and incinerate this sludge. It was essential that the sludge filters . . . *heart of any sewage treatment plant* . . . would dewater rapidly, continuously and automatically at the lowest possible cost. Conkey Sludge Filters were selected and have provided *better filtration* . . . fulfilling each necessary requirement perfectly.

Typical Conkey Sludge Filter features are the effective plastic backing plates for filter cloth support, the Uscolite pipe lines and drainage bells, the efficient double scraper arrangement, specially formulated protective coatings and many newly developed components made of special plastics.

Bridgeport, Chicago, many other cities . . . private industry in many places . . . all have found that creatively engineered Conkey Sludge Filters "do a better job" and do it at minimum cost. Bulletin No. 100 on Conkey Filters belongs to every progressive sewage engineer. Write for your copy today.

Other General American Equipment:

Turbo-Mixers, Evaporators, Thickeners, Dewaterers, Dryers, Towers, Tanks, Bins, Pressure Vessels

OFFICES IN PRINCIPAL CITIES

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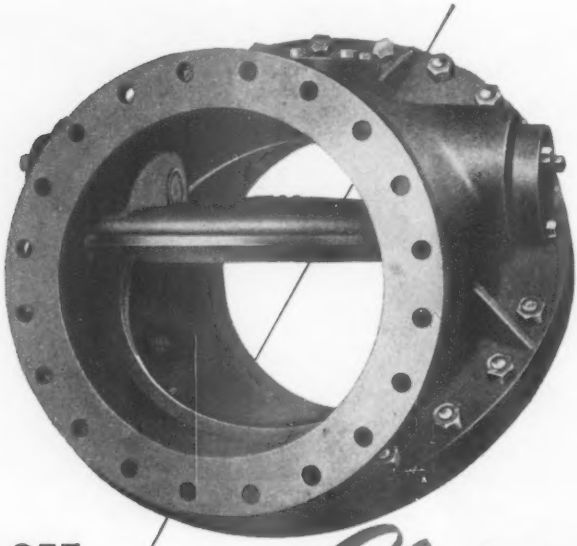


YOU GET

Cushioned Closing

WITH

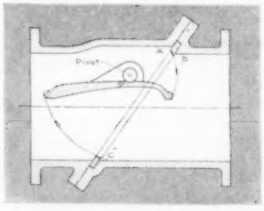
CHAPMAN

TILTING DISC CHECK VALVES

There's no impact on closing — with this valve by Chapman. The balanced disc rides the flow smoothly—uses the fluid or gas itself to cushion the closing action. The disc lifts away from the seat easily on opening; closes quickly, positively — yet quietly.

Consequently, there's no rubbing on the seats —little wear on hinge pins and bearings. Repair needs are at a minimum—maintenance costs low.

Chapman Tilting Disc Check Valves are available in either iron or steel. Write today for catalog with complete technical information.



Cross-section of the Chapman Tilting Disc Check Valve illustrating the way that the balanced disc is supported on the pivot, with arrows showing the travel of the disc. A feature of the design is that the disc seat lifts away from the body seat when opening, and drops into contact when closing, with no sliding or wearing of the seats.

The Chapman Valve Mfg. Co.
INDIAN ORCHARD, MASS.

NOW— FILTROS HIGH PERMEABILITY AIR DIFFUSER PLATES

Recognizing the trend throughout the Activated Sludge Process Field, to the use of higher permeability plates (40 to 80 Permeability), we now offer in these ratings the same qualities for which Filtros plates have long been famous in the low permeability field. The advantages of Filtros exclusive round grain construction have been proven by years of service in some of the outstanding plants in the country using low permeability plates.

A FEW EXAMPLES:

MILWAUKEE, WIS.

This outstanding plant is equipped almost 100% with Filtros Plates, many of which are still in use after 25 years of service.

PEORIA, ILL.

Filtros plates installed in 1931 are giving excellent results after 20 years of service.

CHICAGO

North Side Plant

The original installation of Filtros plates was made in 1928 and replaced last year after 22 years of service.

Let Us Help You!

If you are considering the construction of an Activated Sludge Process Sewage treatment plant or are having difficulty with the diffuser system in your present plant, the assistance of Filtros Engineers is available to you. The attached coupon will bring you complete information on our products and services.

Send this coupon NOW!

FILTROS, Inc.
Box 126
East Rochester, N.Y.

☐ Please send descriptive literature on Diffuser Media.
☐ Have representative call.

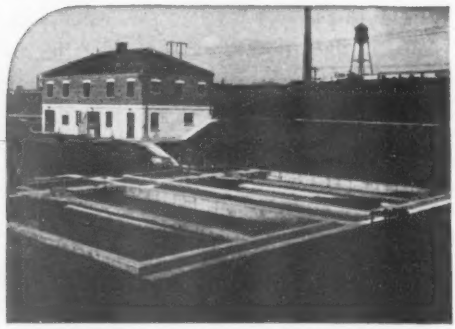
Municipality .....

Name ..... Position .....

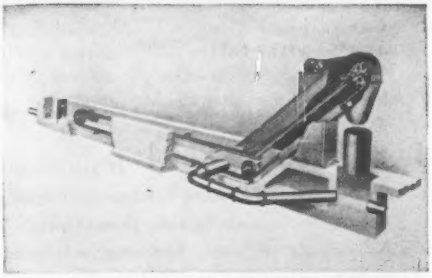
Address .....

for the "BIGS" and the "smalls"

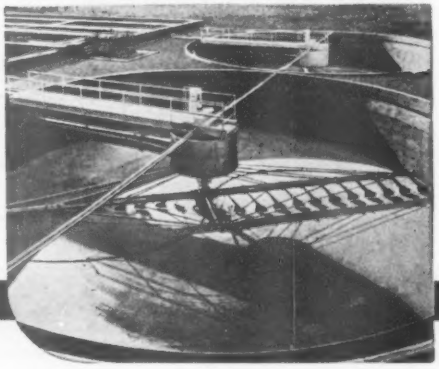
REX provides *proved* equipment!



REX CONVEYOR SLUDGE COLLECTORS combine the well-known advantages of the rectangular settling tank with a rugged and efficient form of sludge removal mechanism. Whether handling primary sludge or light flocculent solids, their performance is efficient and economical.



REX GRIT EQUIPMENT with its exclusive recirculating principle, effectively separates and removes inorganic solids from liquids. No grit washer is required. Rugged construction assures long, economical service.



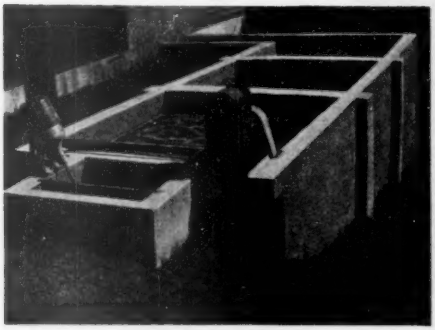
REX TOW-BRO SLUDGE COLLECTORS assure accurate control of sludge removal over a wide range of withdrawal rates through their exclusive suction principle. Sludge is removed immediately on contact instead of the usual plowing or scraping. Greater sludge concentration, greater operating flexibility, and a clearer effluent are a few of the many advantages.

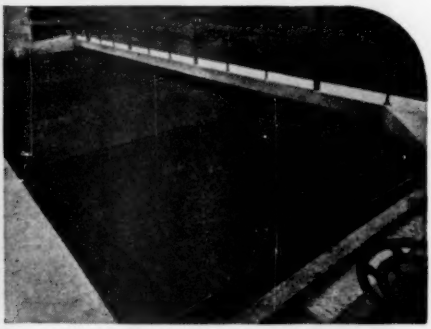
Large plant or small . . . primary or complete treatment . . . domestic or industrial waste, Rex Sanitation and Process Equipment is right for all.

Rex engineers consider the requirements of the small plant as well as the large . . . provide equipment that exactly suits the requirements. Equipment for the smaller plants is not just "scaled down" but is designed and built for the specific problems encountered. Conversely, large plant units are built for the job they must do.

Too, Rex answers the problem of the overloaded plant . . . offers equipment that can frequently expand existing capacities without enlargement of plant size.

In any plant, Rex provides unequaled efficiency . . . capacity . . . sets the standards for economical, long-life operation. Specially trained Rex sanitation engineers will be happy to assist you with your individual problems. For complete information, write for your copy of Bulletin 48-41. Chain Belt Company, 1606 West Bruce Street, Milwaukee 4, Wisconsin.

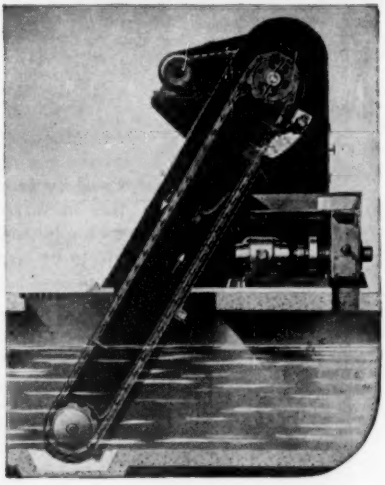




REX SLO-MIXERS AND FLASH MIXERS assure rapid dispersement of chemical throughout the liquid, followed by a gentle, multi-stage slow mixing for optimum floc formation. Rex Slo-Mixers eliminate short-circuiting and effect savings in chemicals.

REX VERTI-FLO delivers a highly clarified effluent with an extremely short detention period. It provides maximum tank capacity for any desired tank size and maximum practical weir length. The combination of large weir length and low vertical velocities assures a clearer effluent, for greater capacity at minimum cost.

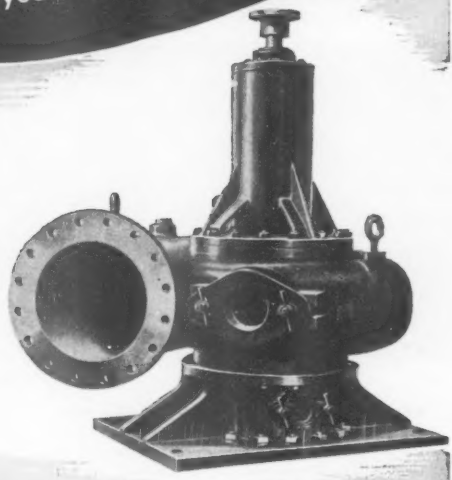
REX MECHANICALLY CLEANED BAR SCREENS AND TRITURATORS are neat, streamlined units that provide an efficient means of removing large solids from liquids and reducing them in size. Reduced material is returned into the sewage flow for quick and efficient handling in settling tanks and digesters.



CHAIN BELT COMPANY REX SANITATION EQUIPMENT

when it's pumps, think of Economy

backed by over thirty years of specialized experience



The Mixed Flow Volute Pump illustrated is just one of the many types in the extensive line manufactured by Economy Pumps, Inc. Available in capacities to 80,000 G.P.M., it is designed for service where large volumes of liquids without heavy solids are to be handled at high speeds.

Maintenance expense is held to a minimum. Case records show Economy Pumps operating for fifteen to twenty years without replacement of major parts. However, should repairs be necessary, all parts subject to wear are renewable.

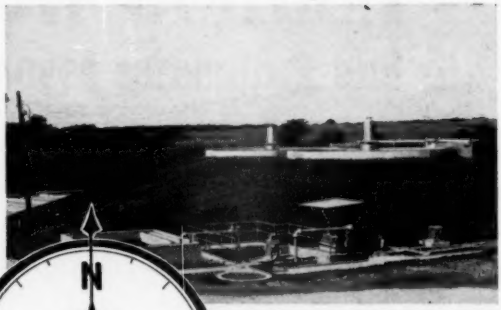
Catalog No. F-1049 gives complete design and construction details. Address Dept. AC-9 for your copy.

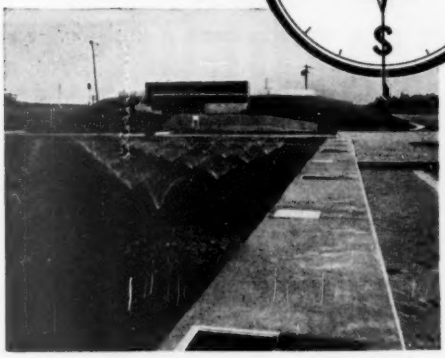
Centrifugal, Axial and Mixed Flow Pumps for all applications

Economy Pumps Inc.

DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO

SEDALIA MISSOURI GOES MODERN





The three waste treatment plants at Sedalia, Missouri—the North, West and South Plants—have been completely modernized, utilizing all existing structures and equipment where economies in construction could be effective.

NORTH PLANT P.F.T. Controlled Digestion System with 2 - 30' floating covered digesters and #170 digester heater is included in this plant which utilizes the existing Imhoff tank as a secondary clarifier, also providing a new trickling filter to supplement the old P.F.T. fixed nozzle unit.

WEST PLANT The P.F.T. Controlled Digestion System at this plant was developed by modernizing two existing unheated digesters with scraper mechanisms with two P.F.T. floating cover digesters and supplying heat with a P.F.T. #170 heater. The existing P.F.T. fixed nozzle filter and final clarifier were used without change.

SOUTH PLANT A completely new P.F.T. Controlled Digestion System with a 35' P.F.T. floating cover and #100 digester heater replaces the old septic tank at this plant. The old contact filters were converted to sludge beds.

All three plants now embody the ultimate in modern "P.F.T. Controlled Digestion" systems including P.F.T. floating covers, P.F.T. supernatant selectors, P.F.T. digester heaters and P.F.T. gas safety equipment. All three digester heaters are also arranged to automatically supply the building heating requirements.

Burns & McDonnell Engineering Co., Kansas City, Mo., Consulting Engineers.

P.F.T. **PACIFIC FLUSH TANK CO.**

Waste Treatment Equipment Exclusively Since 1893

4241 RAVENSWOOD AVE. CHICAGO 13, ILLINOIS

NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • JACKSONVILLE • DENVER

Common sense design assures easy operation
The stuffing box plate, cast integral with the head, combines with the packing and bronze stuffing box nut to seal off the operating thread. Nothing—water, sediment or ice—can reach the thread to damage it or hinder its operation. Winter or summer, the Mathews Modernized Hydrant is *dependable*—an important factor in neighborhood safety.
MATHEWS
HYDRANTS
Made by R. D. Wood Company
Public Ledger Building, Independence Square
Philadelphia 5, Pa.
Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

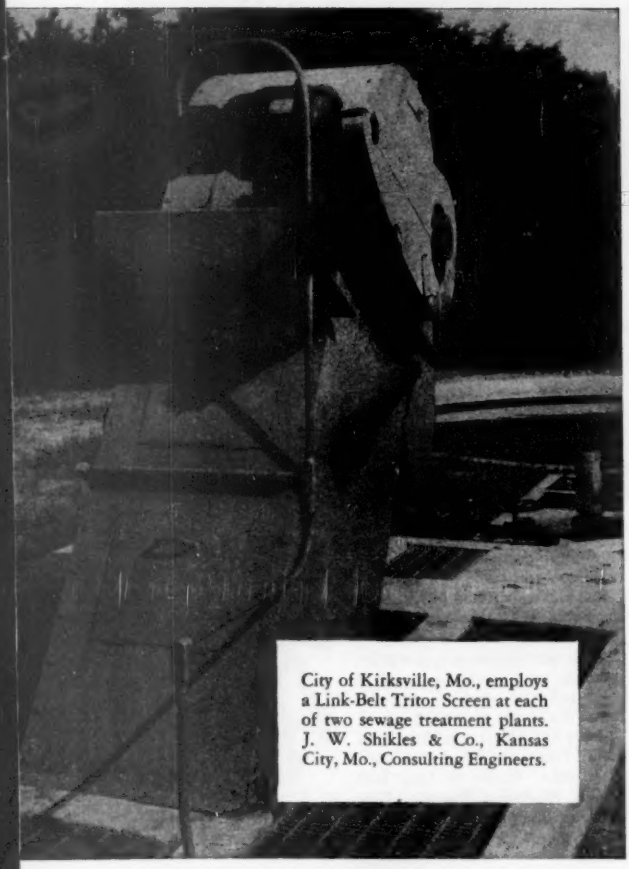
Mathews Modernized Hydrants offer these advantages:

Compression-type valve prevents flooding • Head turns 360° • Replaceable head • Nozzle sections easily changed • Nozzle levels easily raised or lowered without excavating • Protection case of "Sand-Spun" cast iron for strength, toughness, elasticity • Operating thread only part to be lubricated • All working parts contained in barrel—removable without excavating • A modern barrel makes an old Mathews good as new • Available with mechanical joint pipe connections

For low flow . . . for storm conditions

TRITOR SCREEN

efficiently removes screenings and grit



City of Kirksville, Mo., employs a Link-Belt Tritor Screen at each of two sewage treatment plants. J. W. Shikles & Co., Kansas City, Mo., Consulting Engineers.

LINK-BELT combines bar screen and grit chamber in one economical unit

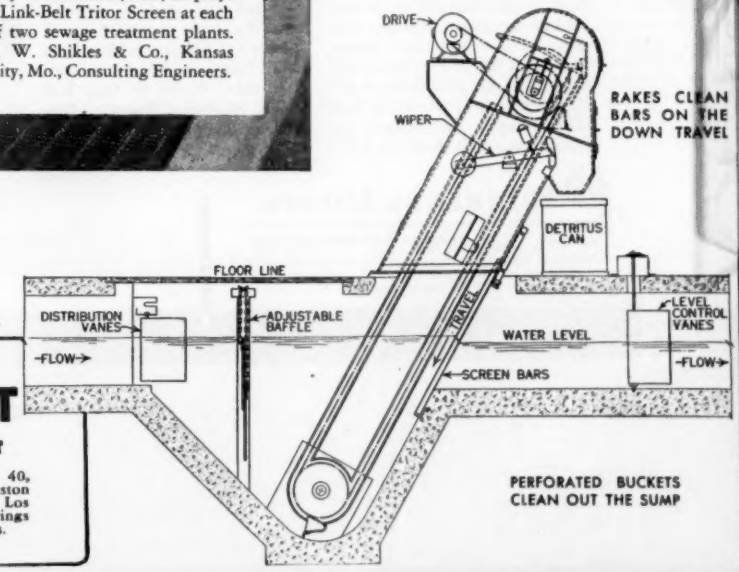
OVER 70 small and medium size treatment plants enjoy the savings provided by the Link-Belt Tritor Screen.

It combines the functions of a mechanically cleaned bar screen and grit chamber in a machine that is economical and easy to install. Used ahead of comminutors or screenings shredders, the Tritor removes large solids to reduce wear on cutting parts. Two adjustable baffles provide velocity control for minimum flows.

When Tritor Screens are installed in conjunction with screenings shredders, screenings may be shredded and returned to the sewage flow during periods of low flows when no grit is coming to the screens.

For details on Tritor Screens and other equipment in the broad Link-Belt line, call the office near you. A Link-Belt sanitary engineer will be glad to give you complete information.

12.427

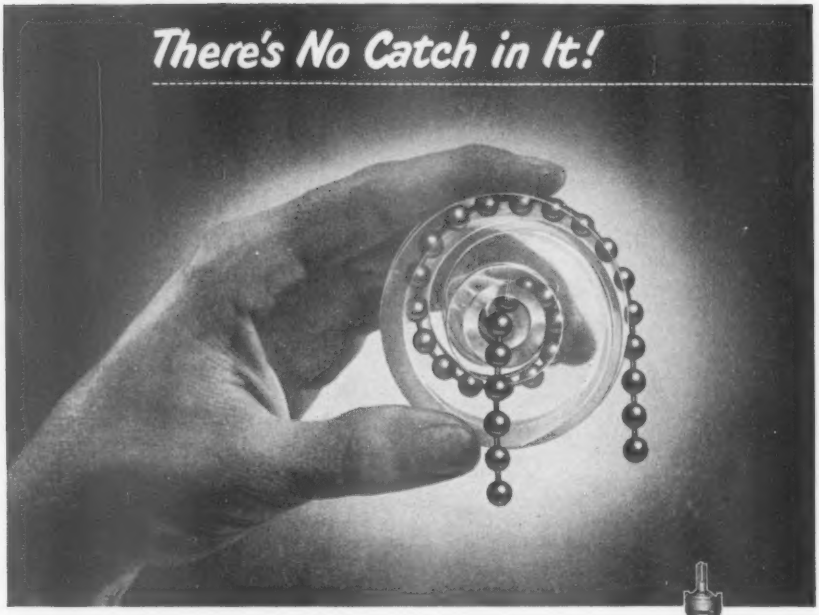


LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Philadelphia 40, Chicago 9, Indianapolis 6, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Springs (South Africa). Offices in principal cities.

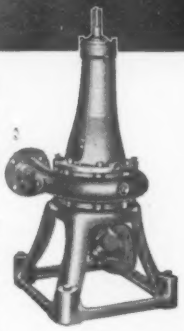
There's No Catch in It!



What is it? It's a plastic model of the amazing new "Bladeless" impeller developed by Fairbanks-Morse pump engineers for Figure 5400 solids-handling pumps.

Why no catch in it? Because, unlike conventional impellers, there are no blades to catch and hold fibrous trash. It makes possible a truly "non-clog" pump. The chain in the illustration follows the water path through the single channel impeller and shows clearly that there's no "catch" possible. And that's important from a maintenance and operating cost angle because the ordinary solids-handling pump often must be dismantled as much as twice daily to clear clogged impellers.

This new advance in pump design is typical of the constant research and product improvement that make possible the high quality and efficient performance of all Fairbanks-Morse products. Fairbanks, Morse & Co., 600 South Michigan Avenue, Chicago 5, Illinois



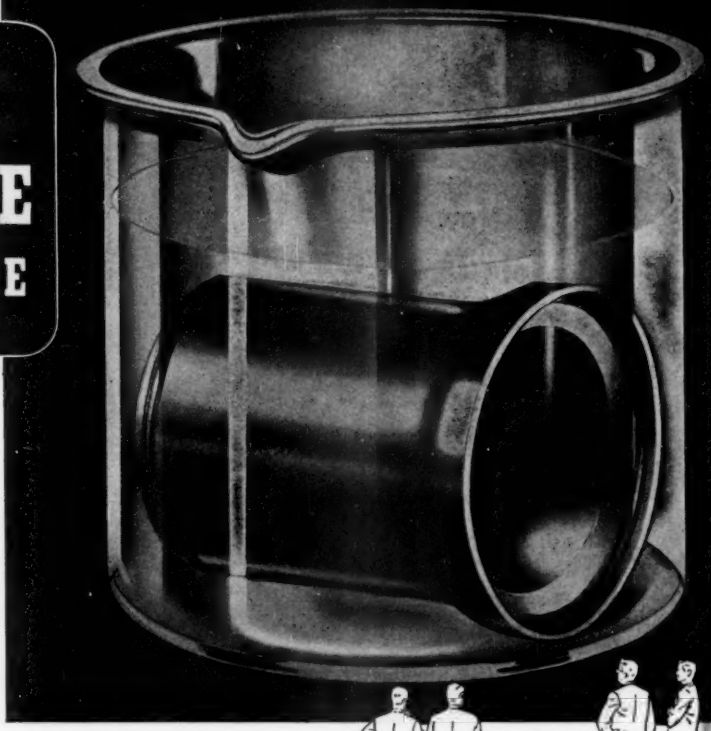
Fairbanks-Morse Figure 5400 solids-handling pump, featuring the "single channel" impeller. Phantom view of impeller clearly shows that there are no "blades" to catch or damage pumped material.

FAIRBANKS-MORSE,

a name worth remembering

PUMPS • SCALES • ELECTRIC MOTORS AND GENERATORS • DIESEL LOCOMOTIVES • DIESEL, DUAL FUEL AND GASOLINE ENGINES • HOME WATER SERVICE EQUIPMENT FARM MACHINERY

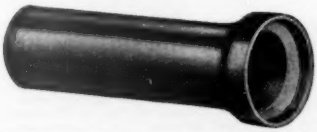
SPECIFY CLAY PIPE AND BE SURE



CLAY PIPE IS THE *ONLY* PIPE THAT INCLUDES ACID TESTS IN ITS A.S.T.M. SPECIFICATIONS

When you write Clay Pipe into your specifications you've given the best guarantee in the world that the pipe will outlive for years, and even centuries, the investment in the project. The clay itself is chemically inert. By the Clay Pipe Industry's exclusive process of VITRIFICATION, the material is fired and bonded together into the only pipe known that maintains its resistance to corrosion forever. In addition to these basic, unmatched qualities, careful controls over each operation give you denser, stronger, better Clay Pipe — of *uniformly* high quality. You can specify Clay Pipe with confidence, secure in the knowledge that Clay Pipe does not disintegrate from acid attack — that it *never wears out.*

NATIONAL CLAY PIPE MANUFACTURERS, INC
100 W. LaSalle St., Rm. 2100, Chicago 2, Ill.
206 Connally Bldg., Atlanta 3, Ga.
703 Ninth & Hill Bldg., Los Angeles 15, Calif.
311 High Long Bldg., 5 E. Long St., Columbus 15, Ohi



SPECIFY *Vitrified* CLAY PIPE

WRITE FOR DETAILED INFORMATION

Additional information and data on Vitrified Clay Pipe, Wall Coping and Clay Flue Lining sent FREE on request. State your specific questions. Simply contact the regional office nearest you.

C-451-1

Information Courtesy Dept. of Public Works, New York City — Photo by Fairchild Aerial Surveys, Inc.

The vital importance of air diffusion processes to New York City's extensive pollution control program was at once evident to its engineers. Five large plants now use activated sludge or modified aeration treatment, three more are under construction, and several others are planned.

This type of aeration gives the high degree of treatment—at low cost—needed to meet New York City's acute conditions. Dense population, limited plant sites, and odor control are all critical factors.

Porous ceramic diffuser plates and tubes *have been used exclusively* for this program. *And* ALOXITE *aluminum oxide diffusers are installed in four of the five aeration plants now operating—and will be installed in all three under construction.*

May we send you our new booklet, "Porous Media for Filtration and Diffusion"? Its 56 pages are crammed with useful data. No obligation, of course.

CARBORUNDUM

THE CARBORUNDUM COMPANY

Dept. N-91, Refractories Division • Perth Amboy, New Jersey

"Carborundum" and "Aloxite" are registered trademarks which indicate manufacture by The Carborundum Company.

Less Infiltration

TRANSITE* SEWER PIPE offers two basic safeguards that minimize infiltration in sewer lines: *tighter* joints and *fewer* joints.

Transite's special sleeve-type joints make up tight and stay tight in service.

Its long 13-foot lengths reduce the number of joints in the system.

These safeguards cut down the volume usually allowed for infiltration, reducing sewage load on the treatment plant and conserving plant capacity for future needs. Where new treatment facilities are planned, this reduced infiltration may permit consideration of a smaller plant with resulting economies.

Other Transite Economies—Transite's long lengths help maintain uniform grades; fewer joints reduce turbulence in the line. These advantages, added to Transite's unusually smooth interior, mean better flow qualities (Kutter's N=.010). This often permits designing the system with flatter grades and shallower trenches. Or, as an alternate economy, pipe of smaller diameter may be specified.

Transite Sewer Pipe is made of asbestos, cement and silica by a special manufacturing process that employs steam curing to develop greater corrosion resistance and strength. It is available in four strength classes in sizes to 36", permitting selection of the pipe best suited to trench conditions, and frequently eliminating the need for concrete cradles.

For further details, write Johns-Manville, Box 290, New York 16, N. Y.

JM

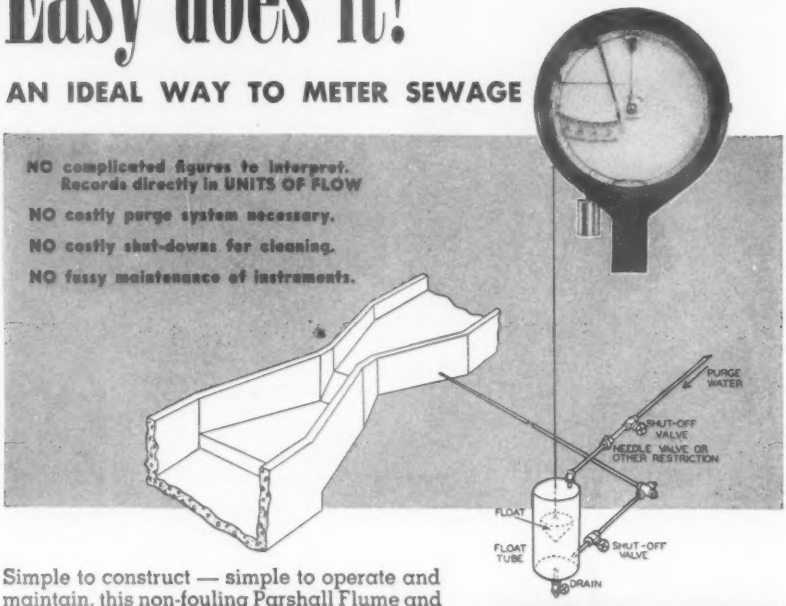
*Transite is a Johns-Manville registered trade mark

. . . Johns-Manville

TRANSITE SEWER PIPE . . .

Easy does it!

AN IDEAL WAY TO METER SEWAGE

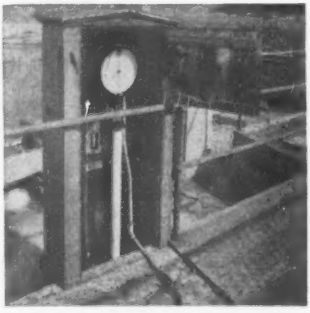


Simple to construct — simple to operate and maintain, this non-fouling Parshall Flume and Foxboro Weir Meter combination answers any call for dependable accuracy and trouble-free operation in sewage metering.

The Foxboro Weir Meter is available, not only for direct reading of flow from a Parshall flume, but also from triangular weirs, Cippoletti weirs and rectangular weirs. Also available for measurement of level in ranges from 0-5" to 0-40 feet.

Combining simplicity and reliability with high accuracy, the instrument utilizes a bakelite cam for translation of fluid level into direct flow measurements. Other features include micrometer zero adjustment on cable drum; positive protection against overrange; weather-proof and corrosion resistant case and mechanism.

Write for Data Sheet 831-1. **The Foxboro Co., 1629 Neponset Ave., Foxboro, Mass., U.S.A.**



Foxboro Weir Meter measuring tannery waste liquid flowing over V-Notch weir. Initial accuracy maintained throughout 4 years' service. Sewer rental calculated from chart record and integrator.

FOXBORO DIRECT-READING WEIR METERS

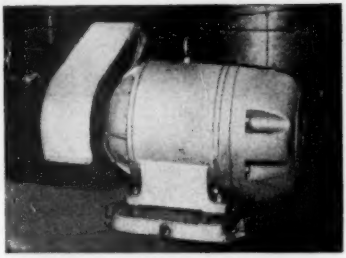
FACTORIES IN THE UNITED STATES, CANADA AND ENGLAND

EARLY PLANNING PAYS OFF

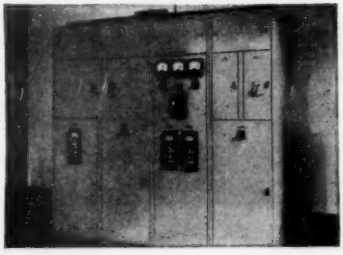
General Electric offers latest electrical ideas to city officials, consultants, machinery manufacturers

A modern sewage disposal plant requires the complete co-ordination of electrical, mechanical and architectural features by a sewage disposal specialist: the consulting engineer. To the consulting engineer, his clients, and the machinery builder, General Electric offers years of experience in the application of electric equipment to sewage treatment.

Call on G-E application and design engineers early in the planning stage. They will expertly select and integrate components to form a completely co-ordinated electrical system . . . the heart of every modern sewage treatment plant. *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*



MOTOR reliability is always of primary importance. G-E application engineers select motors with correct operating characteristics and structural features for each particular application.



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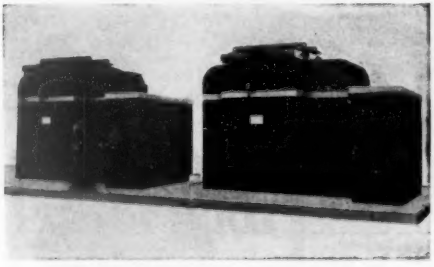

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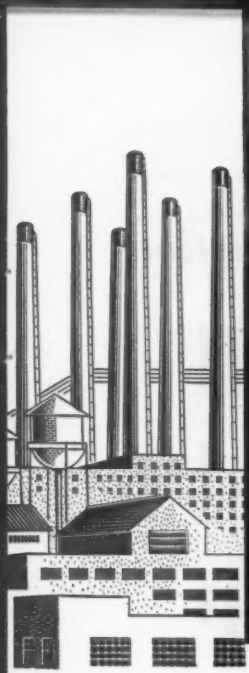

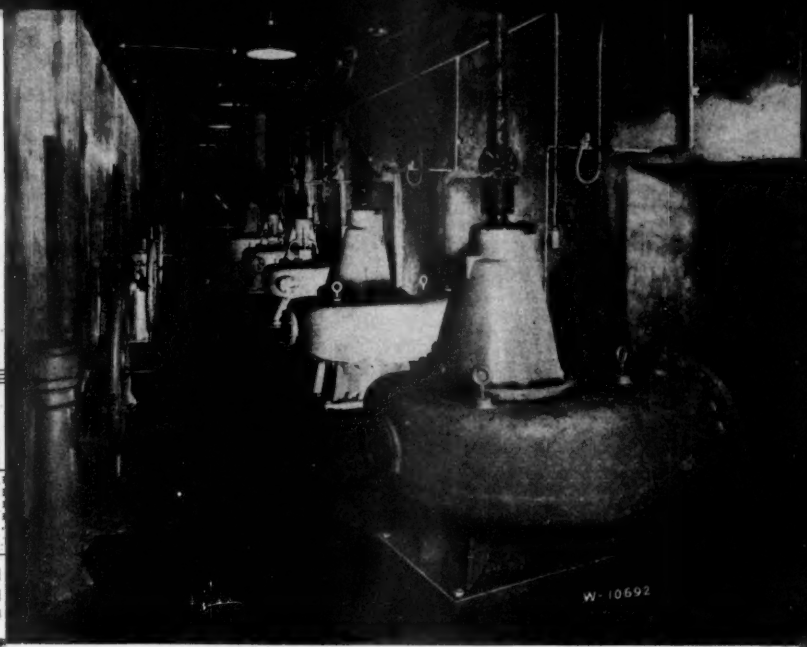

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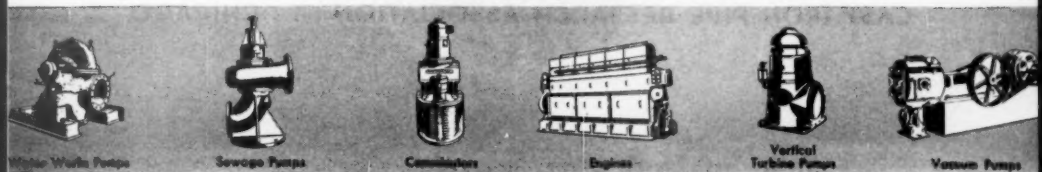

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 23 | SEPTEMBER, 1951 | Number 9

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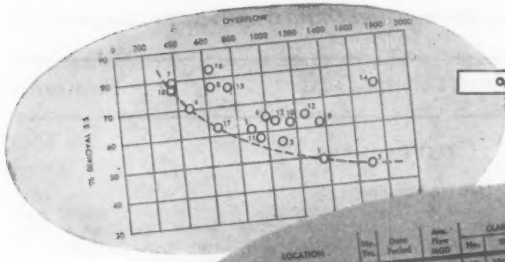

Operating Data on Dorr Sifeed Clarifiers—

radial flow—round or square units. Chart graphically illustrates results given in table below.

LOCATION	No. Yrs.	Dates Tested	Ave. Flow MGD	CLARIFIERS No.	CLARIFIERS Size	CLARIFIERS W.D.	Det. Per.	O'Flow Gal.	SUSP. SOLIDS Raw	SUSP. SOLIDS Eff.	SUSP. SOLIDS % Rem.
Washington, Blue Plains Pls.	2	1944-45	136.3	12	106' Dia.	14	1.52	1350	165	83	49
Gary, Ind.	4	1941-44	30.11	4	75' Sq.	10	2.5	900	346	146	61
Winnipeg, Man.	2	1943-44	32.8	3	115' Dia.	12	1.98	1100	346	129	59
Battle Creek, Mich.	5	1938-43	4.97	2	80' Dia.	10	2.66	498	283	83	70
Buffalo, N. Y.	3	1939-41	135	4	140' "	15'	1.6	1698	309	114	46
Albuquerque, N. M.	7	1939-46	5	1	80' "	13.2	3.21	993	254	91	64
Yakima, Wash.	1	1943	9.0	4	90' "	9	4.32	532	110	33	70
Appleton, Wis.	7	1938-45	4.6	2	70' "	10	2.90	623	276	63	77
Baltimore, Md.	4	1939-44	99.5	3	170' "	12	1.64	1968	514	93	61
Springfield, Ohio	4	1937-40	14.8	3	90' "	10	1.58	1160	168	63	63
Mansfield, Ohio	3	1944-45	9	1	65' "	12	2.36	903	308	97	68
Cedar Rapids, Ia.	9	1936-44	4.21	1	70' "	11.5	1.98	1068	364	122	63
Austin, Texas	2	1944-45	5.64	3	75' "	15	1.69	1275	263	93	64
Newark Memphis, Wis.	4	1942-45	7.93	3	75' "	10	3.0	1720	691	160	77
Detroit, Calo.	3	1939-43	46	4	140' "	9.7	2.24	720	107	44	59
Shell-trpark, Wis.	1	1944	0.4	2	50' "	10	2.8	562	343	69	80
Tipchard, Mich.	3	1943-45	1.66	2	40' "	9	3.5	660	236	57	76
Warren, Mich.	8	1938-45	4.3	2	90' "	7.5	3.33	370	320	20	93

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Sewage Works

MEASUREMENT OF SLUDGE DRYING BED PERFORMANCE

By T. R. Haseltine

Partner, The Chester Engineers, Pittsburgh, Pa.

Until the adaptation of the vacuum filter to sewage sludges, almost every sewage plant had sludge drying beds. The application of sewage sludge to sand beds is still, by far, the most common means of drying it. Despite this fact, no phase of sewage treatment has received less scientific treatment, or less mention in operating reports of various plants.

As a result of long experience and careful observation the operator of a well-managed plant usually forms an opinion (or maybe only gets a hunch) that one depth of application is better than another, alum is or isn't of benefit, sludge from one tank dries better than that from another, and so on. Seldom, if ever, can he present any convincing mathematical evidence in support of his opinions, let alone formulate the performance of his beds or forecast the effect of changes in their mode of operation. Results obtained at one plant cannot be intelligently compared with those obtained at another plant.

No doubt, the lack of a scientific approach to sludge bed operation is due to the large number of variables affecting it. Obviously, climatic and atmospheric conditions (such as temperature, humidity, rainfall, air velocities, and alternate freezing and thawing) play an important role and are only imperfectly controlled, even when glass enclosures are provided. Certainly the depth of application of the wet sludge, the presence or absence of coagulants, and the moisture content of the sludge removed influence the bed performance. Other factors, which may or may not be significant, are the source and type of original sludge; the extent of its digestion; the age, composition, and concentration of the applied sludge; and the method of transferring that sludge from digestion tanks to the beds—that is, gravity flow, pumps, air lifts, etc. In the past, it has seemed almost impossible to ascribe a specific result to a single factor.

Fundamental Concepts

About ten years ago the writer came to the conclusion that the units commonly used to measure sludge bed performance were all wrong, and that before any scientific approach to the problem could be made, it would be necessary to have a better scale by which to measure. The three units most commonly used are as follows:

1. Number of fillings (or applications) per year. This is meaningless unless correlated with the depth of the applications and the solid content of the sludge applied.

2. Cubic yards (or other volumetric measurement) of wet sludge drawn per year. This must be correlated with bed area and sludge solids to have any significance.

3. Pounds of solids applied per square foot per year. This is more scientific than the other units, but the mere fact that beds handle, say, 25 lb. of solids per square foot per year does not mean that they could not have handled 40 lb. if more sludge had been

available or if the beds had not been idle part of the time.

It seemed that a more logical criterion would be the pounds of solids applied per square foot per 30 days of actual bed use. This unit has been termed "gross bed loading." For example, if sludge containing 10 per cent solids is applied 12 in. deep and removed after 40 days, the gross bed loading is $\frac{62.5 \times 0.10 \times 30}{40}$, or 4.69 lb. per square foot per 30 days. Theoretically this result should be multiplied by the specific gravity of the wet sludge, but because of the paucity of specific gravity records, that refinement is omitted.

Table I shows the gross bed loading at 14 different plants over periods of 1 to 14 years. Geographically, the plants included range from Salinas, Calif., to Huntington, N. Y., and from Rochester, N. Y., to San Antonio, Tex. However, as a concession to weather effects, data for the winter months at the northern plants have been excluded wherever possible. The table includes primary sludge, chemically precipitated sludge, primary and filter humus sludge, and primary and activated sludge; digested in Imhoff tanks, and heated or un-

TABLE I.—Performance of Various Sludge Drying Beds

Plot Point	Plant	Year	Solid (%)		Gross Bed Loading[1]	Net Bed Loading[1]	Reference
			As Applied	As Removed			
(a)	Butler, Pa.[2]	1937	9.2	37.9	4.95	1.88	Plant record
	Butler, Pa.[2]	1938	8.3	34.9	5.71	1.99	Plant record
	Butler, Pa.[2]	1939	5.8	52.5	3.07	1.61	Plant record
(b)	Butler, Pa.[2]	1940	8.1	33.2	3.26	1.08	Plant record
(n)	Butler, Pa.[2]	1941	7.6	37.3	2.80	1.05	Plant record
	Butler, Pa.[2]	1942	6.9	31.7	4.43	1.40	Plant record
	Butler, Pa.[2]	1943	6.2	26.7	4.46	1.19	Plant record
	Butler, Pa.[2]	1944	5.9	34.1	3.42	1.17	Plant record
	Butler, Pa.[2]	1946	6.3	33.8	3.90	1.32	Plant record
	Butler, Pa.[2]	1947	6.1	31.7	3.31	1.05	Plant record
	Butler, Pa.[2]	1948	6.4	35.2	2.98	1.05	Plant record
(c)	Cleveland, Ohio	1930	12.0	56.0	7.50	4.20	(2)
(d)	Cleveland, Ohio	1931	13.0	42.0	6.82	2.86	(2)
	Cleveland, Ohio	1932	10.0	37.0	8.06	2.98	(2)
	Cleveland, Ohio	1933	9.0	30.0	7.28	2.18	(2)
	Cleveland, Ohio	1934	8.0	35.0	6.04	2.11	(2)
	Cleveland, Ohio	1935	9.0	43.0	5.84	2.52	(2)
	Cleveland, Ohio	1936	9.0	45.0	6.43	2.90	(2)
	Cleveland, Ohio	1937	9.0	40.0	6.38	2.80	(2)
	Dayton, Ohio	1931	4.08	37.0	3.75	1.39	(1)
	Dayton, Ohio	1932	5.06	36.0	4.75	1.71	(1)
	Dayton, Ohio	1933	4.72	48.5	2.27	1.10	(1)
	Dayton, Ohio	1934	4.87	56.0	1.85	1.04	(1)
	Great Neck, N. Y.	1937	4.5	32.3	2.04	0.66	(3)
	Grove City, Pa.[2]	1938	4.75	—	1.95	—	Plant record
	Grove City, Pa.[2]	1939	3.60	38.6	2.02	0.78	Plant record
	Grove City, Pa.[2]	1940	3.90	44.3	2.26	1.00	Plant record
	Grove City, Pa.[2]	1941	4.13	49.7	1.44	0.72	Plant record
	Grove City, Pa.[2]	1942	4.75	50.0	1.32	0.66	Plant record

[1] As defined in text.
[2] Drying season 7 to 9 months; other plants 12 months.

TABLE I.—Performance of Various Sludge Drying Beds—Continued

Plot Point	Plant	Year	Solids (%)		Gross Bed Loading[1]	Net Bed Loading[1]	Reference
			As Applied	As Removed			
(e)	Huntington, N. Y.	1937	8.4	27.0	10.80	2.92	(3)
(k)	Lancaster, Pa.[2]	1938–39	2.80	24.5	1.76	0.44	(4)
(g)	Marion, Ohio	1929	7.15	32.3	6.18	2.00	(7)
(f)	Port Washington, N. Y.	1937	4.70	26.0	7.95	2.07	(3)
	Rochester, N. Y.[2]	1922	10.2	—	6.95	—	(5)
	Rochester, N. Y.[2]	1923	8.4	—	7.43	—	(5)
	Rochester, N. Y.[2]	1924	10.0	—	7.48	—	(5)
	Rochester, N. Y.[2]	1925	9.2	—	8.64	—	(5)
	Rochester, N. Y.[2]	1926	9.2	—	5.07	—	(5)
	Rochester, N. Y.[2]	1927	8.1	—	6.32	—	(5)
	Rochester, N. Y.[2]	1928	6.5	—	3.50	—	(5)
	Rochester, N. Y.[2]	1929	7.3	—	5.58	—	(5)
	Rochester, N. Y.[2]	1930	7.2	—	4.95	—	(5)
	Rochester, N. Y.[2]	1931	6.3	—	4.75	—	(5)
	Rochester, N. Y.[2]	1933	6.0	—	4.52	—	(5)
	Rochester, N. Y.[2]	1934	7.0	—	6.52	—	(5)
	Rochester, N. Y.[2]	1935	6.6	—	4.42	—	(5)
	Rochester, N. Y.[2]	1936	6.4	—	4.58	—	(5)
(j)	Rockville Centre, N. Y.	1937	5.4	24.5	6.78	1.66	(3)
(m)	Salinas, Calif.	1932–33	5.4	62.8	2.15	1.35	Plant record
	San Antonio, Tex.	—	4.0	45.5	1.90	0.86	(6)
(h)	Springfield, Ill.	1932	9.2	54.1	4.93	2.66	Annual report
	Springfield, Ill.	1933	8.4	—	3.50	—	Annual report

heated single-stage and two-stage digesters; and applied in various depths to open or glass-covered beds. In some cases coagulants were used to aid sludge drying.

Table I shows that the solid content of the sludge removed from the beds ranged from 62.8 to 24.5 per cent. Naturally, the lower the solid content of the sludge removed, the shorter will be the time on the beds and, hence, the higher the gross bed loading. Slight variations in solid content of sludge removed may be of little practical significance, but wide variations affect the cost of cleaning beds and the amount of sand replacement required.

In order to take into consideration the variable of solid content of sludge removed, a second unit, termed "net bed loading," is proposed. It is the product of the gross bed loading multiplied by the per cent solids in the sludge removed.

The gross and net loadings of Table I are plotted in Figures 1 and 2, respectively. Despite numerous scatterings, there appears to be a definite relationship between the solid content of the applied sludge and the bed loadings. The relationships may be expressed by $Y = 0.96X - 1.75$ (1) and $Z = 0.35X - 0.5$ (2) in which X is the percentage of solids in the applied sludge, Y is the gross bed loading, and Z is the net bed loading.

The wide range of plants and sludges included and the reasonable conformance of the data to the empirical formulas given, seem to justify the conclu-

sion that, next to temperature, the solid content of the sludge applied to drying beds is the most important single factor influencing bed performance. The moisture content of the sludge as removed is probably the next most important factor.

A study of some of the points that do not conform to Eqs. 1 and 2 is enlightening. Inspection of Table I and Figures 1 and 2 indicates several classes of non-conformance, as follows:

1. Points e, f, j, and k (Huntington, Port Washington, Rockville Centre, and Lancaster) show unusually high gross loadings, which are believed due to the low solid content of the sludge removed (27.0, 26.0, 24.5, and 24.5 per cent, respectively). In Figure 2 these points are much closer to the general average, although the first three are still high. This shows what can be done in the way of crowding beds when necessary. It must be remembered,

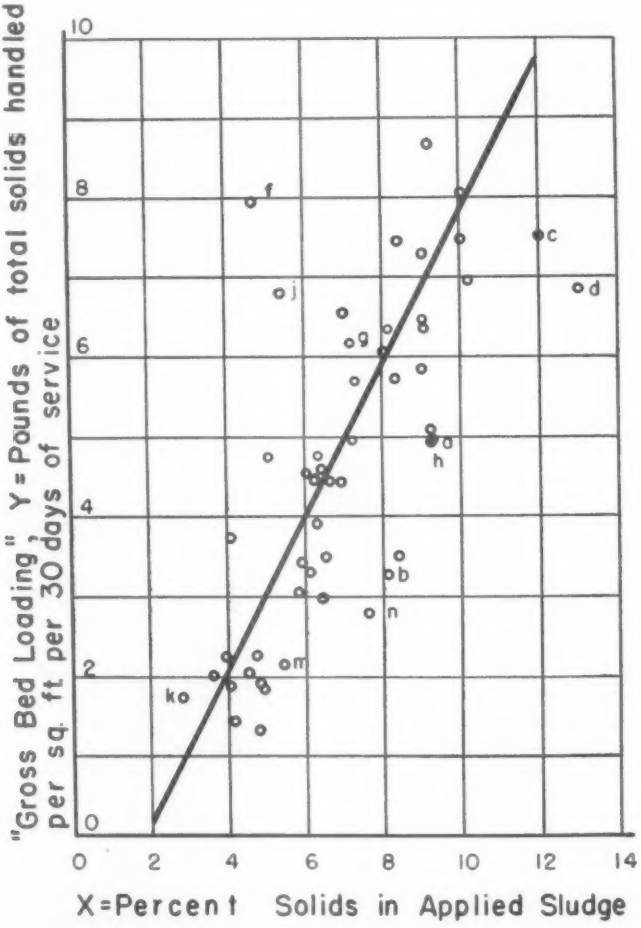

FIGURE 1.—Gross bed loading, $Y = 0.96X - 1.75$.

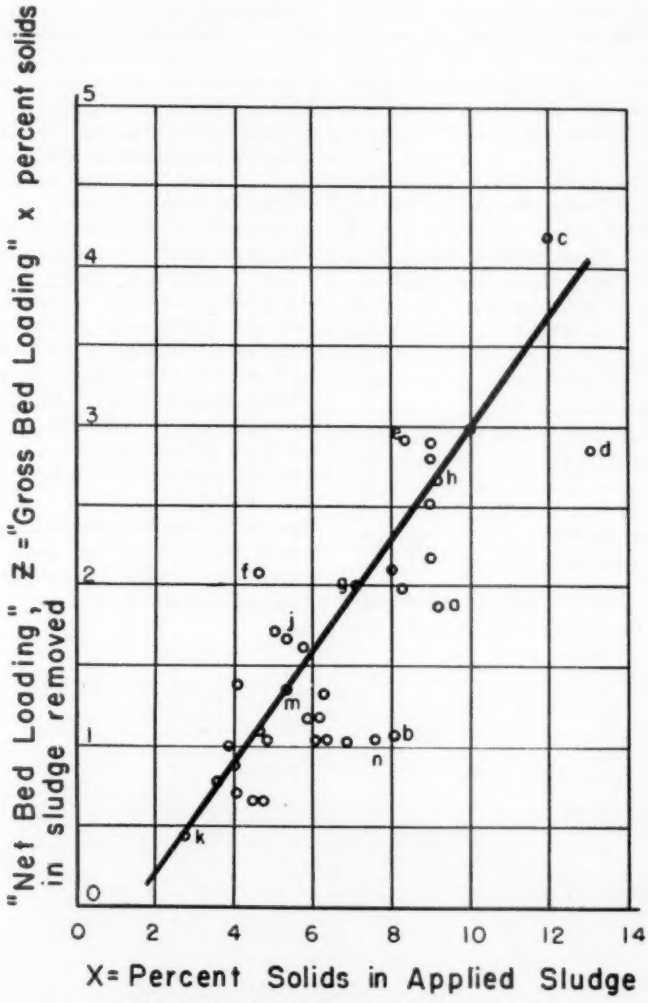

FIGURE 2.—Net bed loading, $Z = 0.35X - 0.5$

however, that the costs of cleaning and sand replacements are increased by such a practice.

2. Points c, m, and h (Cleveland 1930, Salinas, and Springfield 1932) are the direct opposite and show low gross loadings, which are believed due to the high solid content of the sludge removed (56.0, 62.8, and 54.1 per cent, respectively). In Figure 2 points m and h are almost in direct conformance.

3. Point c (Cleveland 1930) falls considerably above the line in Figure 2, despite the fact, just noted, that it is below the line in Figure 1. Referring to the original data (2), it is found that the average air temperature at

Cleveland during that year was 61° F., whereas the next highest annual temperature was 55° F., and the average of the seven other years was 53° F. It is only logical to expect increased efficiency at higher temperatures.

4. Point d (Cleveland 1931) falls considerably below the line in both figures. This point represents a solid content of 13 per cent in the applied sludge. This is the highest solid content of any of the sludges reported in Table I. It is possible that Eqs. 1 and 2 do not apply to such heavy non-fluid sludges, although more data are needed to confirm this conclusion.

5. Points a, b, and n refer to Butler 1937, 1940, and 1941 performance. These points all fall considerably below the line in both figures. The explanation for this poor performance is given later in this paper.

It is believed that if more were known about local conditions, the nonconformance of many of the other points could be similarly accounted for. It is interesting to note how close point g conforms to the equation in each figure. This point represents results obtained at Marion, Ohio (7) in 1929, with two glass-enclosed beds that were given special attention so that the sludge was always removed as quickly as economically feasible, and the beds were never allowed to remain idle.

Eqs. 1 and 2 are purely empirical, and possibly might be changed if more data were available. However, the many other variables will always play such an important role that perfect conformance could never be obtained. The relationships indicated by Eqs. 1 and 2 are, at best, annual averages over a wide geographical area with numerous climatic variations. Therefore, there is no reason to expect the actual results obtained at any single plant under some specific atmospheric condition to conform exactly to the equations.

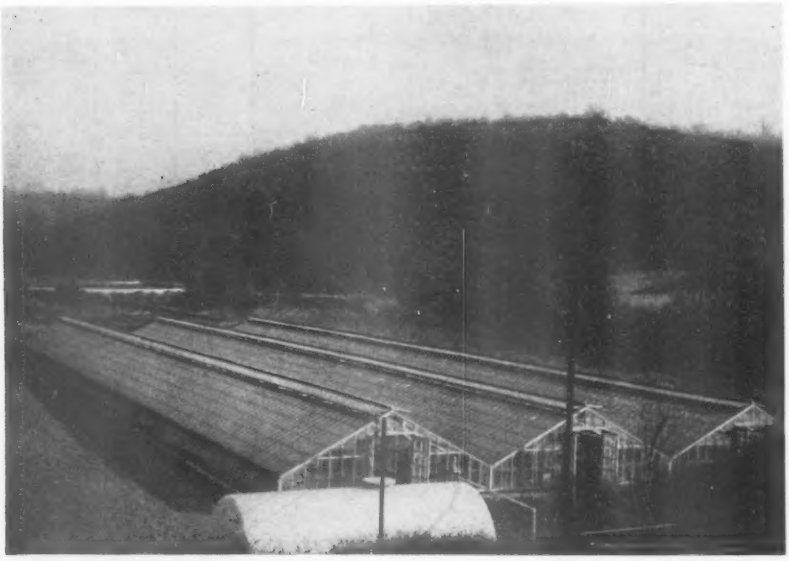

FIGURE 3.—Sludge drying beds at Butler, Pa., sewage treatment plant.

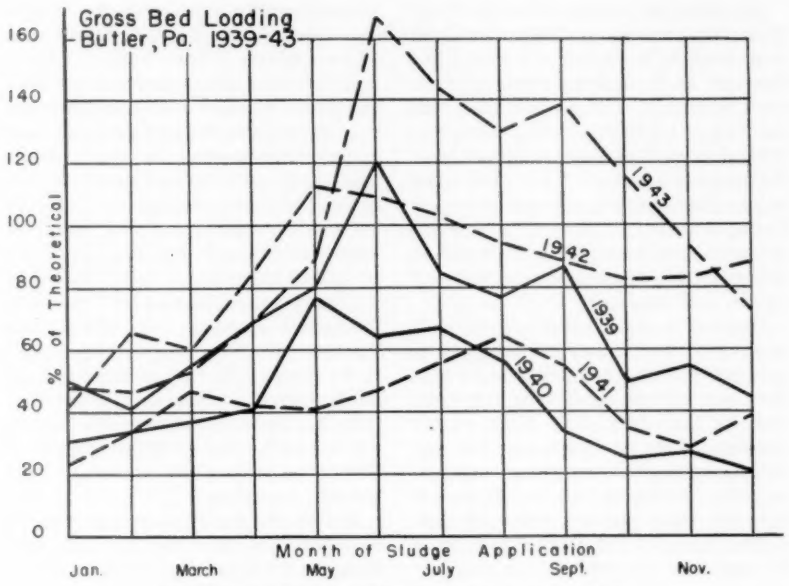

FIGURE 4.—Gross bed loading, Butler, Pa., 1939–43.

However, if the solid content of the applied sludge is known, it is possible to calculate theoretical bed loadings by use of Eqs. 1 and 2. The actual loadings obtained may then be expressed as percentages of those theoretical loadings. By correlating the variations in these percentages with one or more of the other variables affecting sludge bed performance, it is possible to demonstrate and calculate the significance of that other variable. By no other means known to the writer is it practical to eliminate the important effects of solids concentration in the sludge applied and removed when studying these other variables.

The remainder of this paper is devoted to illustrations of this procedure. Because the writer did not fully develop the principles previously set forth until after most of his actual operating experience had been gained, it is necessary to use performance data accumulated prior to their development. Throughout the following discussion the reader is asked to bear in mind that had the above principles been known at the time the operating data were obtained, the mode of operation might have been changed and different or more complete data been collected.

Sludge Drying at Butler

The Butler, Pa., plant served about 30,000 people in 1937–43. At that time it had 12 beds, each 24 ft. by 45 ft. in plan and of conventional design. All the beds were glass enclosed (Figure 3). Bed arrangement was such that the center line of four beds was under each of the three ridges of the enclosures. Although the outer concrete walls were quite high and the sides of the glass enclosures had only a single course of ventilators, careful comparisons showed no significant difference between the results obtained on the three rows of beds. The relatively large number of small glass-covered beds made the Butler plant ideal for studying sludge bed performance.

Inasmuch as temperature is of the utmost importance in sludge drying, it is reasonable to expect the actual bed loadings to be higher during summer than winter. On the other hand, the theoretical loadings or efficiencies, calculated from Eqs. 1 and 2, are, at best, only annual averages. Therefore, when actual loadings are expressed as percentages of the theoretical, it is to be expected that those percentages will be above 100 in hot weather and below 100 in cold weather.

Figures 4 and 5 indicate the bed loading and efficiencies expressed as percentages of the theoreticals that were actually obtained at Butler from 1939 to 1943, inclusive. They clearly indicate that the loadings and efficiencies were higher during the summer than during the winter. However, they also show that the over-all annual performance of the Butler beds, particularly during 1940–41, was considerably below the general averages expressed by the Eqs. 1 and 2. This is also apparent from points b and n in Figures 1 and 2.

In 1939 and previous years, the Butler plant provided chemical precipitation during the summer and only primary sedimentation at other times. The sludge drying bed area was entirely adequate. Sludge could be allowed to remain until it was unusually dry. Because of this condition, the gross bed loadings for 1939 (shown in Figure 4) were frequently below the theoretical averages, even during the summer. However, the long drying periods resulted in an unusually high solid content in the sludge removed from the beds. Therefore, the actual net bed loadings during the summer of 1939 were well above the theoretical normals (see Figure 5).

In 1940 the Butler plant was changed to provide complete treatment the year around. This resulted in the production of additional sludge; more diges-

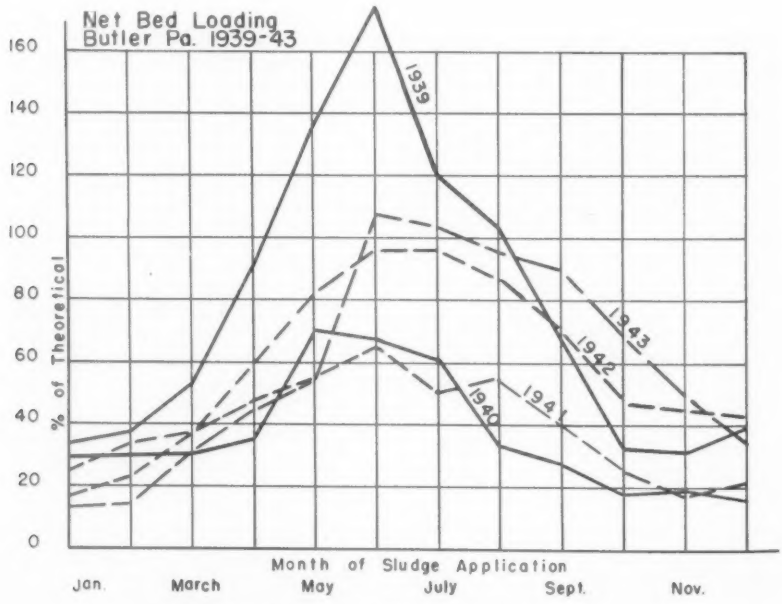

FIGURE 5.—Net bed loading, Butler, Pa., 1939–43.

tion capacity was provided, but no additional drying beds were constructed. As a result, by 1943 conditions were reversed. Digested sludge accumulated faster than it could be dried on the beds. Retention time on the beds had to be cut to a minimum; sludge was removed with as low a solid content as practicable, despite the additional cost required for such removal and bed resanding. As indicated in Figure 4, such operation resulted in gross bed loadings well above the theoretical average. However, despite these high gross loadings, the low solid content of the sludge as removed gave low net loadings, as indicated in Figure 5.

The Butler enclosures were erected in 1927 and had wooden frames. By 1940 the wood had become so soft that roof glass was continually slipping down and exposing the beds to the weather. The enclosures were completely overhauled during June and July, 1941. During that time the beds were exposed to all rainfall. At the same time, the side walls still interfered with free air circulation. Thus, the enclosures were worse than none at all. These conditions, in part at least, explain the poor performance of 1940–41. However, as explained later, there were other contributing factors during 1940.

Determination of Optimum Depth of Sludge Applications

The writer first came to Butler in April, 1937. Prior to that time the operators had varied the depth of application of sludge to beds from time to time, but, as was to be expected, other conditions had been so variable that neither they nor the writer could formulate any idea as to what depth was most efficient. During the following summer sludge applications ranged in depth from 7 to 12 in., and by the end of the summer the writer came to the conclusion that 9 in. was probably the optimum depth of application. However, that conclusion was really nothing more than a good "hunch." No figures could be given to positively substantiate it, let alone indicate how much, if any, better a 9-in. application was than an 8-in. or a 10-in. application.

At the time these data were collected, the writer had not yet conceived of the units of gross and net bed loadings for measuring the performance of sludge drying beds, let alone developed the formulas for computing the theoretical loadings or efficiencies. Since then the actual loadings and their percentages of the theoretical have been calculated from the original records. These data are shown in Table II. It will be noted that with a 9-in. depth of application, both the gross and net bed loadings, expressed as percentages of the theoretical, were materially higher than they were for any other depth of application, thus affording mathematical proof of the "hunch" acquired at the time the experiments were made. Had the units of bed loading and the formulas for calculating their theoretical values been known at that time, it is probable that the optimum depth could have been determined with much more certainty and in much less time.

When the writer took over the operation of the Grove City, Pa., plant in 1938, he assumed that a 9-in. depth of application would also be optimum at Grove City, as the two communities were only 20 miles apart. However, there were actually a number of differences, the most important of which were:

1. The Grove City sludge was considerably lower in solid content than that of Butler, due to the fact that Grove City utilized the activated sludge process of treatment.
2. Grove City had both open and covered beds.

After a year's experience it was suspected that sludge bed performance was not as good as it should be, particularly on the covered beds. The Grove

TABLE II.—Effect of Various Depths of Sludge Application, Butler, Pa., June–September, Incl., 1937

Depth Applied (in.)	Number of Fillings	Solids On (%)	Drying Time (days)	Solids Off (%)	Bed Loading			
					Gross		Net	
					Actual	%[1]	Actual	%[1]
7	2	8.8	22.0	40.45	4.37	65.2	1.76	68.1
8	7	10.6	24.9	40.01	5.48	65.0	2.19	68.2
9	7	9.14	22.7	35.50	5.90	83.9	2.12	78.6
10	6	8.55	33.5	42.38	4.10	63.4	1.73	69.5
11	1	6.7	36.0	40.9	3.21	68.4	1.31	70.7
12	2	8.7	43.5	42.25	4.06	61.4	1.71	67.3

[1] Per cent of theoretical.

City plant, which served about 6,500 people, had two 1,000-sq. ft. covered beds and two 1,500-sq. ft. open beds. Because the beds were so large and few in number in proportion to the size of the plant, it was difficult to conduct satisfactory experiments at Grove City. However, in 1939, an attempt to investigate optimum depths of application was made and it was decided that 9 in. was an optimum depth of application on the open beds, but that 14 in. would be better on the covered beds. The first five columns of Table III show some of the original data collected, but the bed loadings shown were calculated several years later.

When the bed loadings, expressed as percentages of the theoretical, are considered, there can be no question but what a 14-in. depth gave better results than a 10-in. depth on the covered beds. The data on the open beds are not conclusive, due to the fact that the ex-

TABLE III.—Effect of Various Depths of Sludge Application, Grove City, Pa., 1939

Date Applied	Depth Applied (in.)	Solids On (%)	Drying Time (days)	Solids Off (%)	Bed Loading			
					Gross		Net	
					Actual	%[1]	Actual	%[1]
(*a*) Open Beds								
July 28	8½	3.4	18	34.1	2.51	165	0.86	125
Aug. 2	9¾	3.95	22	49.0	2.74	134	1.35	152
Aug. 17	9	3.55	19	40.0	2.63	159	1.05	142
July 10	9	3.5	16	34.1	3.08	191	1.05	145
Average	—	—	—	—	—	175	—	143.5
(*b*) Covered Beds								
May 9	10	3.8	20	41.8	3.00	158	1.26	147
May 31	10	4.1	20	42.4	3.24	147	1.37	146
Average	—	—	—	—	—	152.5	—	146.5
May 15	14	3.5	28	55.8	2.74	180	1.53	211

[1] Per cent of theoretical.

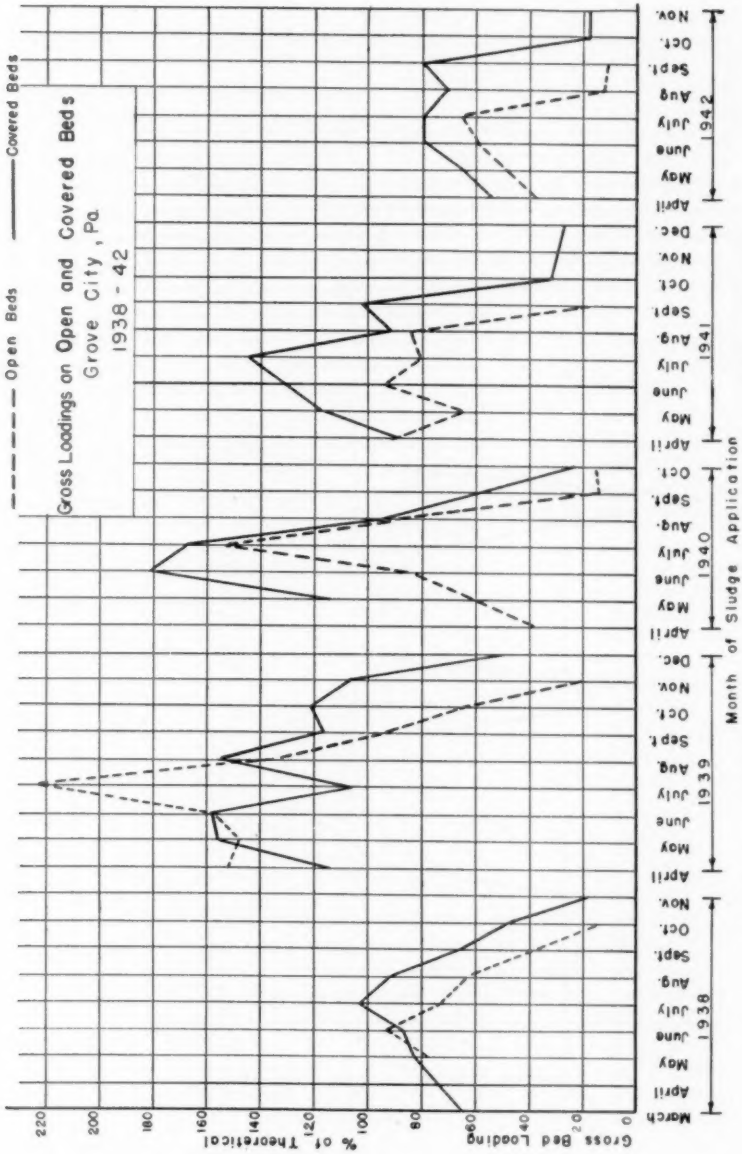

FIGURE 6.—Gross loadings on open and covered beds, Grove City, Pa., 1938–42.

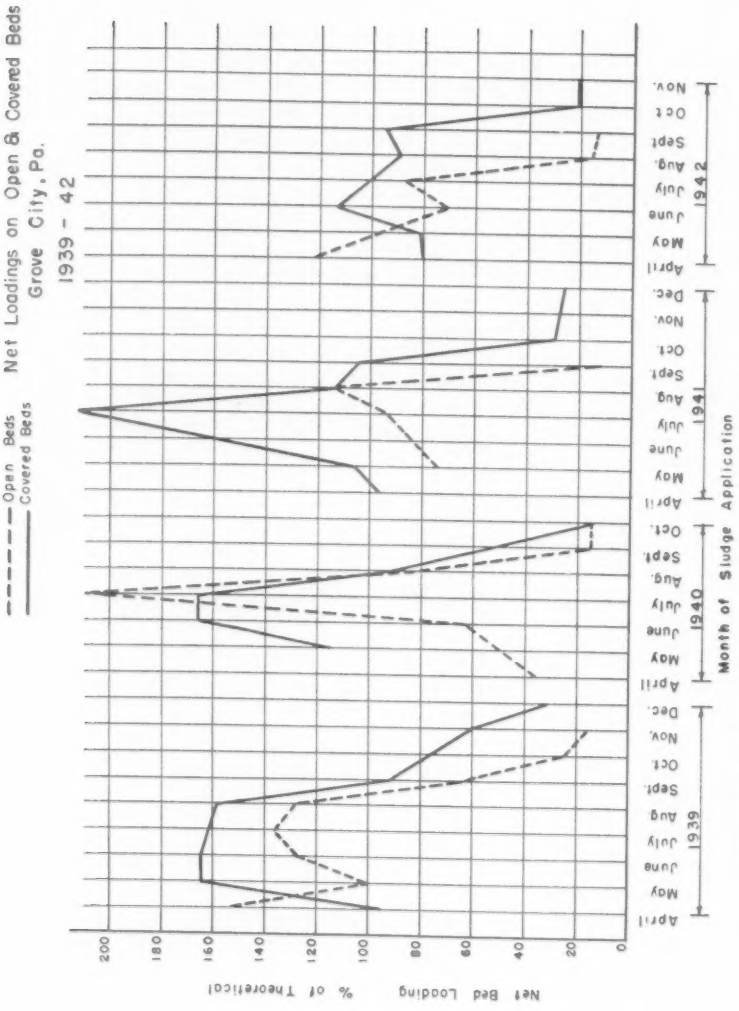

FIGURE 7.—Net loadings on open and covered beds, Grove City, Pa., 1939-42.

treme variation in depths of application was only from 8½ to 9¾ in.

Comparison of Open and Covered Beds

Figures 6 and 7 show the average monthly loadings, expressed as a percentage of the theoretical, obtained on both the open and covered beds at Grove City during the period 1938 to 1943, inclusive. It will be noted that during the summer months of 1938 and 1939 the loadings on the open beds were frequently as high or higher than they were on the covered beds, whereas during the last three years, the covered beds consistently handled heavier loads. This at least indicates that increasing the depth of application to the covered beds was a step in the right direction.

This comparison between open and covered beds is given simply as an illustration of the use of the units, formulas, and procedures herein presented. It should not be considered indicative of the general difference between open and covered beds that might be expected elsewhere. This is true not only because of the relatively small number of sludge applications made at Grove City during the five-year period, but also due to the peculiar layout of the Grove City beds. They were so arranged that half of the runoff from the glass enclosures fell directly on one side of the open beds, thus materially affecting their performance.

Effect of Coagulants on Sludge Bed Performance

It is believed that the procedure of comparing bed loadings expressed as percentages of the theoretical is particularly advantageous in studying the value of alum or other chemicals as

TABLE IV.—Effect of Alum on Drying Sludge from Secondary Digester, Butler, Pa., 1939–40

Month	No. of Beds Drawn	Alum Used (lb./cu. yd.)	Sludge Applied		Drying Time (days)	Sludge Removed @ Solids	Bed Loading			
							Gross		Net	
			% Solids	% Organic			Actual	%[1]	Actual	%[1]
June	2	1.67	6.4	46.0	23.5	67.5	3.85	87.5	2.60	149.5
	2	0.00	5.2	45.0	19.0	61.0	3.84	118.0	2.34	177.3
July	5	1.67	5.7	43.7	26.0	55.1	3.06	82.3	1.69	112.7
	5	0.00	5.8	55.8	25.8	56.0	3.17	83.1	1.78	106.2
Aug.	6	1.67	5.2	42.0	24.8	52.9	2.94	90.5	1.56	118.0
	6	0.00	5.4	44.9	31.5	54.4	2.41	70.0	1.31	94.2
Sept.	4	1.67	4.9	44.6	25.3	32.1	2.70	95.0	0.87	71.2
	4	0.00	5.0	44.5	28.5	31.8	2.45	80.5	0.78	62.4
Oct.	4	1.67	4.9	46.0	44.8	29.7	1.54	52.3	0.46	37.6
	4	0.00	4.9	48.8	55.5	25.3	1.25	42.4	0.32	26.2
Nov.	2	1.67	4.4	45.8	52.5	21.8	1.16	47.0	0.25	24.0
	2	0.00	4.6	46.4	79.5	25.2	0.84	32.2	0.21	18.9
Dec.	3	1.67	5.5	48.0	76.7	31.2	1.08	30.6	0.32	22.4
	3	0.00	5.8	47.6	89.7	34.1	0.91	23.8	0.31	20.2
Jan.	2	1.67	7.5	60.0	63.0	37.7	1.68	30.8	0.63	29.6
	1	0.00	9.0	50.2	59.0	36.2	2.15	31.2	0.78	29.5
Mar.	3	2.50	8.5	48.6	40.3	25.9	2.98	46.5	0.77	31.2
	3	0.00	8.3	47.9	43.3	25.4	2.70	43.5	0.71	29.5
Apr.	4	2.08	9.4	46.4	48.3	33.3	2.72	37.4	0.91	32.6
	2	0.00	9.2	47.9	20.5	30.2	2.56	36.1	0.77	28.3
Average[2]		1.79	5.85	46.1	39.4	40.0	2.46	64.5	1.06	68.6
		0.00	5.95	47.3	42.2	40.1	2.27	60.4	0.99	65.2

[1] Per cent of theoretical. [2] Weighted average.

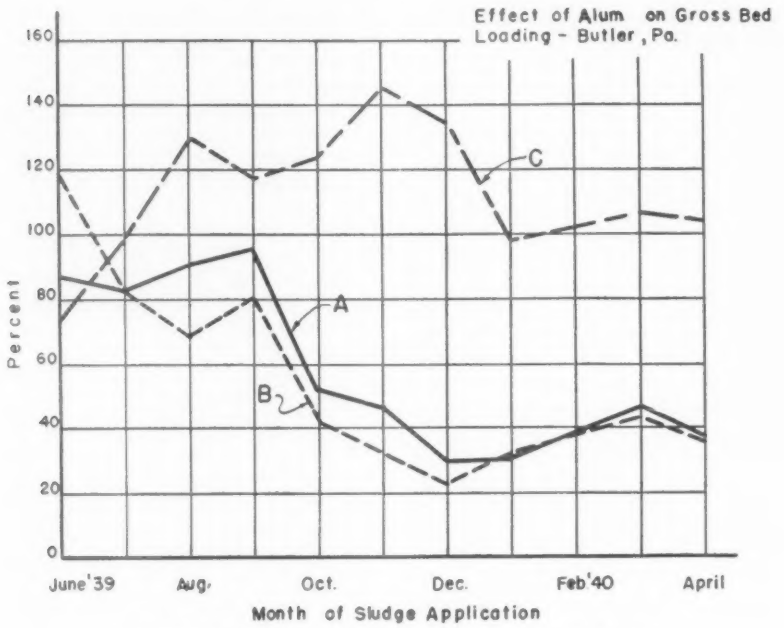

FIGURE 8.—Effect of alum on gross bed loading, Butler, Pa.

sludge drying aids. For several years it had been the custom at Butler to use either alum or ferric chloride as a sludge drying aid during the winter months, but no chemical was used during the summer months. Some doubt arose as to whether or not the chemical was of any real benefit and, if it were of value, why it should not be used the year around. Therefore, from June, 1939, to April, 1940, inclusive, the practice was adopted of using alum on about half of the beds withdrawn. Because it was common procedure to draw two beds at a time, it was a simple matter to assure comparisons being made under equal atmospheric conditions. Some of the data collected during that period are summarized in Table IV, which also shows loadings as a percentage of the theoreticals for each month. It was while these tests were in progress that the units of gross and net bed loading were first used, although the relationship between those units and the solid content of the applied sludge had not yet been discovered. As the weighted average solid contents of the treated and untreated sludges were practically identical, a comparison of weighted averages of actual loadings and efficiencies was just as good as would have been their comparison when expressed as a percentage of the theoreticals. However, such a comparison left much to be desired when the results of certain individual months were considered.

Figures 8 and 9 show the monthly loadings obtained. In those figures, lines A show the loadings, expressed as percentages of the theoretical, for the alum treated applications; lines B show the corresponding data for the untreated applications. Lines C indicate "A" values expressed as percentages of the "B" values; that is, the percentage benefit resulting from

the use of alum in any month is the point on the C line for that month less 100. The curves clearly indicate that the greatest benefit is realized in the autumn when days are growing shorter and colder. Apparently, little, if any, benefit is obtained in the middle of the summer or the dead of winter. As is discussed later, the sludge applied during the spring was of unusual character and so the curves may not show the true advantage of alum in that season.

In 1940, Wiest (4) published results of experiments at Lancaster, Pa., which indicated that activated carbon was of particular value in handling a thin sludge high in organic matter. Because the Grove City sludge was quite similar to that at Lancaster, it was decided to experiment with carbon at Grove City. Table V summarizes the results of those experiments. The first trials on both the open and covered beds indicated carbon to be superior to alum, but later trials did not confirm that conclusion. In fact, the results obtained in August indicated little or no benefit at all from carbon. As previously mentioned, the Grove City beds were too large, and too few in number, to permit the obtaining of adequate experimental data.

Effect of Age of Applied Sludge

Earlier in this paper data were presented to substantiate the statement that, next to temperature, the solid content of the applied sludge is the most important factor influencing bed performance. Formulas were presented to show that both the gross and net bed loadings increase as the solid content of the applied sludge increases. Attention is directed to an exception to that relationship.

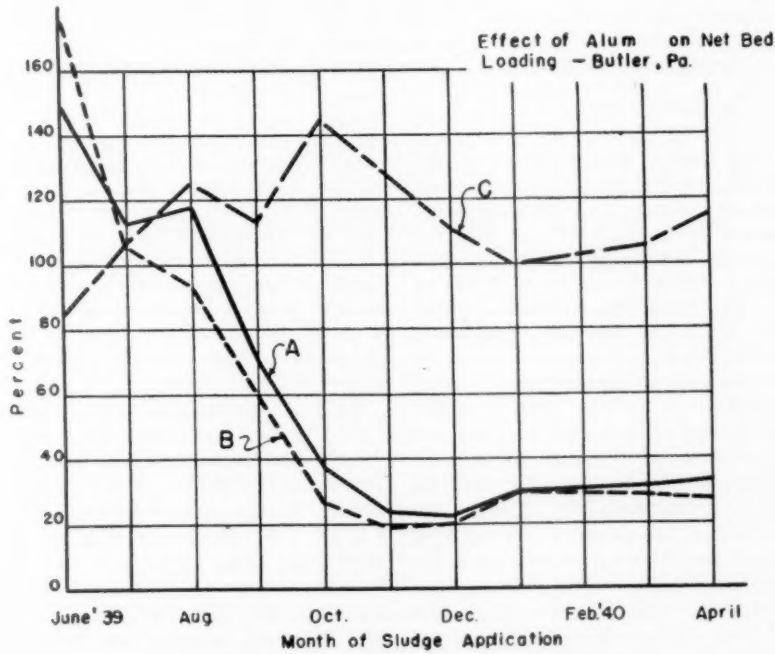

FIGURE 9.—Effect of alum on net bed loading, Butler, Pa.

TABLE V.—Comparison between Alum and Activated Carbon on Sludge Drying at Grove City, Pa., 1940

Date	Sludge Applied		Chemical Used[1]	Drying Time (days)	Sludge Removed % Solids	Bed Loading			
						Gross		Net	
	% Organic	% Solids				Actual	%[2]	Actual	%[2]
(*a*) Covered Beds; 13½-in. Application									
May 3	62.9	3.77	Alum	39	39.4	1.96	148.5	0.77	94.0
May 16	66.0	4.28	Carbon	35	49.2	2.48	105.0	1.22	122.0
June 11	64.6	2.63	Alum	19	36.1	2.81	365.0	1.02	240.5
June 20	61.4	4.22	Carbon	33	48.9	2.59	153.5	1.27	129.8
July 1	60.9	3.12	Alum	22	39.5	2.88	232.0	1.14	193.0
July 23	60.9	4.25	Alum	25	43.0	3.45	148.0	1.49	151.0
July 31	65.2	4.02	Carbon	26	43.3	3.14	149.0	1.36	149.5
Aug. 22	60.8	4.06	None	48	47.3	1.72	80.0	0.81	88.1
Aug. 27	62.0	3.75	Carbon	41	37.2	1.86	100.5	0.69	85.3
(*b*) Open Beds; 9-in. Application									
July 6	61.3	4.10	Alum	21	60.0	2.75	125.5	1.65	175.6
July 11	61.8	3.65	Carbon	15	60.2	3.43	196.0	2.16	277.0
Aug. 2	61.7	4.43	Carbon	43	44.5	1.45	58.0	0.63	60.0
Aug. 5	62.8	3.77	Alum	17	35.2	3.12	167.0	1.10	134.0
Aug. 29	60.6	4.12	None	42	43.8	1.39	62.6	0.61	64.2

[1] Dosage at rate of 3.66 lb. of alum or 0.425 lb. of activated carbon per cubic yard of wet sludge.

[2] Per cent of theoretical.

The original Butler plant provided chemical treatment during the summer and only primary treatment during the remainder of the year; had two rectangular, multi-hopper digestion tanks with a combined capacity of 85,400 cu. ft. The tanks were operated in parallel. When the plant was expanded to include trickling filters, a two-stage digestion program was provided. A new 45,000-cu. ft. circular tank, arranged for heating and gas collection, was constructed to serve as the primary digester, the two old tanks being used together as the secondary digester. In November, 1939, about 25,000 cu. ft. of digesting sludge was transferred to the primary digester, after which it went into operation and received all charges of fresh sludge. However, for several months these charges consisted of only plain sedimentation sludge, as the final settling tank did not go into service until May, 1940. The new digester handled this reduced load very nicely, producing a relatively clear overflow liquor, which was practically the only feed to the old secondary digesters. As a result, the sludge remaining in the old tanks became very thoroughly digested and quite dead.

Table VI compares the drying of this "dead" secondary sludge with that of freshly digested sludge drawn from the new primary digester. The secondary digester sludge contained from 8.4 to 9.3 per cent solids and thus should have given much higher bed loadings than the primary digester sludge, which contained only 5.3 to 6.8 per cent solids. However, such was not the case. The actual loadings, in pounds per

square foot per 30 days, obtained with the thin sludge, were higher than those with the heavy sludge on 5 of the 6 months shown in the table. When the loadings and efficiencies are expressed as percentages of the theoreticals, it is obvious that the thin sludge dried about 20 to 70 per cent better than the heavy sludge. When this was realized, the practice was started of transferring sludge instead of supernatant from the primary to the secondary digesters. These transfers, plus the addition of trickling filter humus to the primary sludge after the middle of May, increased the loading on the secondary digesters and gradually improved the drying qualities of that sludge. However, several months passed before a normal drying sludge was produced.

The poor drying quality of this dead sludge may be even more responsible for the inferior performance of the Butler beds during 1940 than was the disrepair of the glass enclosures previously mentioned (see Figures 1 and 2). It may also have affected the previously described experiments on the use of alum, which extended through the spring of 1940.

Effect of Grit

The accompanying photographs (Figure 10) of the sludge drying beds at Klamath Falls, Ore., were taken in 1934 prior to the installation of a grit chamber at that plant. Whereas normal digested sludge flows evenly over the surface of a drying bed and assumes a practically level surface, the Klamath Falls sludge contained so much grit that it assumed a slope of about 1 on 12. As a result, sludge application depths were excessive near the bed inlet and only about 30 per cent of the bed area could be covered with sludge. Obviously, bed performance was far from satisfactory.

Although the Klamath Falls situation was unusual, it is probable that lesser amounts of grit in the sludge may interfere with its drying to such an extent that the relationships between sludge solids and bed loadings no longer apply. It is believed that excessive grit in the sludge may account for the poor performance of the Butler beds in 1937 (point a in Figures 1 and 2). The writer came to Butler in April of that year. Despite the fact that the

TABLE VI.—Drying of Primary and Secondary Digester Sludge, Butler, Pa., 1940

Month	No. of Beds Drawn	Drawn From	Alum Used (lb./cu. yd.)	Sludge Applied		Drying Time (days)	Sludge Removed % Solids	Bed Loading			
				% Solids	% Organic			Gross		Net	
								Actual	%[1]	Actual	%[1]
Mar.	6	Secondary	1.25	8.4	46.9	46.0	27.4	2.57	40.7	0.71	29.1
	1	Primary	1.67	5.3	49.2	25.0	23.2	2.98	89.0	0.69	51.1
Apr.	6	Secondary	1.39	9.3	46.9	48.0	32.2	2.71	37.8	0.87	31.6
	1	Primary	0.00	6.5	46.1	19.0	30.8	4.81	107.1	1.48	83.1
May	2	Secondary	1.67	8.4	46.4	29.5	36.4	4.00	63.4	1.46	59.8
	5	Primary	0.33	6.6	45.6	23.1	36.0	4.03	87.8	1.46	80.6
June	12	Secondary	0.00	8.4	45.6	26.0	35.0	4.57	72.3	1.60	65.6
	4	Primary	0.00	6.4	46.1	18.75	35.0	4.76	108.1	1.67	96.0
July	8	Secondary	0.00	8.9	43.5	27.5	35.8	4.56	67.0	1.63	62.5
	2	Primary	0.00	6.8	44.0	23.5	33.1	4.03	84.4	1.38	73.3
Aug.	10	Secondary	0.00	8.7	43.2	35.5	31.0	3.45	52.3	1.07	42.0
	4	Primary	0.00	6.8	43.2	26.75	32.7	3.58	75.0	1.17	62.2

[1] Per cent of theoretical.

FIGURE 10.—Sludge drying beds at Klamath Falls, Ore., prior to installation of grit chamber. Note nonflowability of sludge as applied to beds.

plant had a grit chamber, it was found that large amounts of grit were passing into the clarifiers and thence to the digesters during every storm. In November, 1937, alterations to the grit chamber doubled or trebled the amount of grit collected.

Summary

1. It is suggested that sludge bed performance be measured in terms of gross and net bed loadings. "Gross bed loading" is defined as the "pounds of solids applied per square foot per 30 days of actual bed use." "Net bed loading" is the product of the gross loading multiplied by the per cent solids in the sludge removed from the beds.

2. Next to temperature, the solid content of the sludge applied to drying beds is the most important factor influencing bed performance. The moisture content of the sludge as removed is the next most important factor. Unless these factors, as well as temperature, are taken into consideration, it is impossible to measure the effect of the many other variables, of lesser importance, which affect bed performance.

3. Data from a large number of different types and locations of plants indicate that the relationship between average annual bed loadings and the solids in the applied sludge may be expressed by the formulas:

Gross Bed Loading = (0.96 × % solids in applied sludge) − 1.75.

Net Bed Loading = (0.35 × % solids in applied sludge) − 0.5. However, these formulas do not apply to old, thoroughly digested, "dead" sludge or to sludges containing excessive amounts of grit.

4. If the actual bed loadings obtained are first expressed as percentages of the theoretical loadings calculated from the above formulas, and then compared, it is possible to measure the effect of other variables upon sludge bed performance. Examples are given of the use of this procedure in determining optimum depths of wet sludge applications; comparing open and covered beds; or measuring the benefits to be derived from alum or other chemicals used as sludge drying aids.

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NPA APPROVALS FOR SANITATION FACILITIES

Processing of applications for authority to construct water and sewage facilities is moving rapidly in the new Water Resources Division of NPA (see THIS JOURNAL, **23**, 8, 1054; Aug., 1951), according to Harry E. Jordan, secretary, Water, Sewage and Industrial Wastes Joint Committee on Critical Materials. Approvals, being sent on Form CMP–13, bear a specific allotment number. The authority to purchase is based on a DO–T–8 rating. All of the procedure is based on CMP Regulation 6.

Regarding use of the allotment after its receipt, Mr. Jordan, in a letter dated August 8, 1951, says:

It is imperative that every executive receiving an allotment from the Water Resources Division proceed immediately to file his orders with manufacturers or jobbers and that he instruct his contractor, if any, to file his orders immediately, basing them upon the specific allotment number and rating applied to the job.

To make it plain, orders which involve steel, copper, or aluminum components, even though they are properly rated and have an allotment number, can only be accepted by the producer up to the capacity which he has to supply materials.

You must understand that if the first producer/jobber with whom you or your contractor attempts to place a rated order cannot accept it for delivery as specified, you should use all diligence to place the order with someone else who may be able to fill it. These transactions must not be delayed.

If you place an order for delivery in a certain month and the producer/jobber cannot fill it during that month, but can do so in a later month—in the same quarter—if that is acceptable to you, it is in order to do so. If, however, you cannot place the order with anyone for delivery during the quarter (October-November-December) for which it is rated, but someone is willing to accept it for the next quarter (January-February-March), you must apply at once to the Water Resources Division for revalidation for delivery during the later quarter. Do not delay such request for revalidation a moment longer than it takes you to make the decision.

If you do not have a copy of CMP Regulation 6—get it from the nearest NPA field office.

THE EFFECT OF ULTRASONICS ON SUSPENDED MATTER IN SEWAGE

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Subject and Purpose of Study

The term "ultrasonics" is used in acoustics to denote those frequencies which are beyond the limits of the human ear. As stated by Bergmann (1), this would include sound frequencies above 20,000 cycles per second. Since 1880, when the brothers Curie (2) discovered the piezoelectric effect of quartz crystals, and 1883, when Galton (3) developed his "Galton pipe," much research has been done on the phenomena which occur when ultrasonic waves are passed into liquids, gases, and other media.

The effect of ultrasonic vibrations on suspended matter was studied with the intent to put special emphasis on the effect of those phenomena which could be utilized in the field of sanitary engineering. The plan was to observe several types of suspended matter, such as sewage, silt, alum floc, etc., very briefly; to choose one of them, and explore the effect of the vibrations as completely as time and apparatus permitted. After the experimental data were collected, they were to be analyzed with consideration of their possible use in the sanitary engineering field.

Preliminary experiments showed that activated return sludge when exposed to the vibrations would settle more rapidly than sludge which had not been exposed to the vibrations. Upon further experimentation it was found that there was a critical time period of exposure to the vibrations which caused the sludge to settle most rapidly.

Principles Involved

Phenomenon of Coagulation

It has been reported by Bergmann (1) that, "The (ultrasonic) vibrations cause coagulation of the particles of smoke or mist, which then are thrown down very quickly in the nodes." These smokes and mists were produced by tobacco, sal-ammoniac, hydrochloric acid, and similar substances, which were observed while exposed to the ultrasonic waves radiated by quartz crystals at one end of the transparent tubes. These observations were utilized to exhibit the existence of ultrasonic waves and to measure their length.

Later observations by Wood (4) showed that similar coagulation effects could be produced in liquids as well.

> "One of the most surprising and spectacular effects produced by supersonic waves traveling through a liquid is the aggregation of minute suspended particles into a single lump. We powdered anthracite coal, obtaining very fine particles by sifting it through a fine wire gauze and shook that material up in water in a large test tube. Within a few seconds from the time the bottom of the test tube was dipped into the oil fountain, the mass of minute particles gathered together, first into a small then into a large lump, finally uniting into a single pulsating black mass which swam about in the perfectly clear liquid like a tadpole. This aggregation of suspended particles in a liquid is associated in some way with the presence of dissolved air in water, for it was subsequently found out that it does not occur in water which has been freed from dissolved air by boiling."

Piezoelectric Effect

Among the various methods of producing ultrasonic waves, such as the Hartman gas current generator, the magnetostriction generator, the siren, and the piezoelectric generator, the latter was chosen for this experiment because of its adaptability and relative ease of application to the medium.

When mechanical pressure is applied to opposite faces of a quartz crystal, these faces will develop opposite electric charges proportional to the amount of pressure applied. The reverse effect occurs when a direct current is applied over opposite faces of the crystal, causing the crystal to either contract or expand. When an alternating current is applied over the opposite faces of this crystal, the crystal will vibrate mechanically if the frequency of the applied current is equal to the natural harmonic of the crystal or a multiple of this harmonic. Crystals such as tourmaline, zinc blende, sodium chlorate, tartaric acid, Rochelle salt, and many others can be used to demonstrate the piezoelectric effect. All these piezoelectric crystals belong to the system which has three polar axes connecting opposite edges of the prism. These edges are not equivalent, due to small faces which do not occur at odd edges of the crystal. The maximum potential in a crystal is developed when mechanical pressure is applied at the ends of one of the polar axes; conversely, the greatest amplitude of vibration is obtained in a crystal when the potentials are applied to the faces of the crystal which are at right angles to one of the polar axes.

Quartz, belonging to the hexagonal system, has three polar axes and the optical, or axis of symmetry, which is perpendicular to the X, or polar axes. The crystal used, therefore, was cut perpendicular to one of the X-axes.

Quartz Crystal in Ultrasonics

The thickness of the crystal determines its fundamental natural elastic frequency, N_d, and its equation is given by Bergmann (1) as:

$$N_d = \frac{1}{2d}\sqrt{\frac{E}{\rho}}$$

in which d is the thickness of the plate, in cm.; ρ is the crystal density, in grams per cc.; and E is a characteristic modulus of elasticity for the vibration of this type and direction, in dynes per sq. cm. For a quartzplate thickness d, the fundamental frequency, N_d, in kilocycles, is:

$$N_d = \frac{287 \pm 5}{d}$$

Apparatus

Oscillator

To obtain the radio frequency current necessary to vibrate the crystal, the continuous wave circuit of a BC-375-E war surplus radio transmitter was used in conjunction with its TU-26-B tuning unit as master oscillator (see Figure 1). The required power input of the transmitter (24 v. and 10 amp.) and plate voltage of 1,000 v. and plate current of 300 milliamp. was supplied by the PE-37-C dynamotor unit, consisting of a motor generator unit wound on one armature. The necessary input to this dynamotor of 24 v. and 20 amp. of direct current was supplied by two selenium full-wave rectifiers supplying 12 v. each and connected in series. These rectifiers were driven by 115-v. 60-cycle alternating current.

The power density of the crystal is given (5) by the equation:

$$T = 2e^2\left[\frac{1}{\rho_0 v_0}\left(\frac{V}{300d}\right)^2\right]$$

in which T is the energy output per unit area of crystal surface, in ergs per sq. cm.; e is the piezoelectric stress coefficient (quartz $= 5.2 \times 10^4$ e.g.s. units); V is the peak voltage applied; d is the crystal thickness; and ρ_0 and v_0 are, respectively, the density and

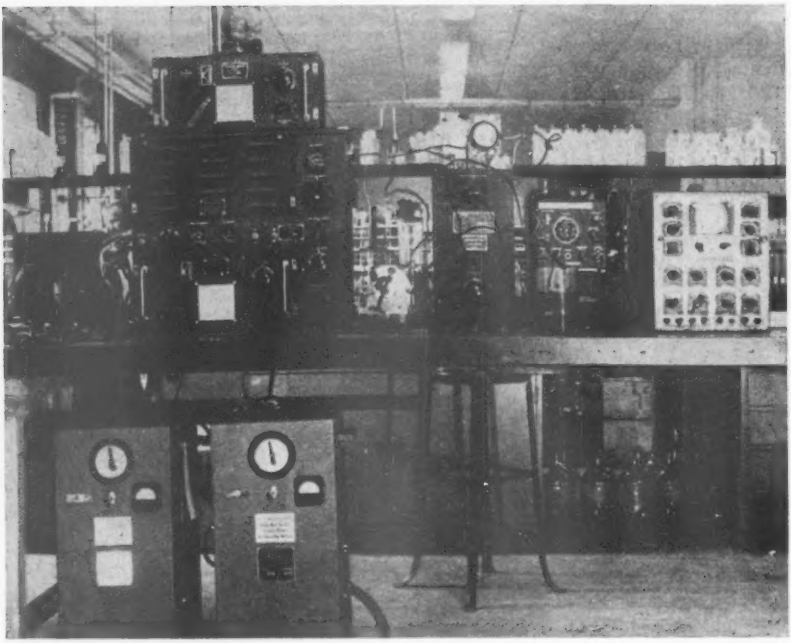


FIGURE 1.—Apparatus used in experiments with ultrasonics on suspended matter in sewage, showing (left to right): Dynamotor, transmitter, variable condenser, induction coupler, crystal and oil bath, frequency meter, and oscillograph. At left below table are the two selenium rectifiers.

velocity of sound in the fluid surrounding the crystal. This equation shows that the square of the voltage applied is directly proportional (all other things remaining equal) to the energy output obtained. The amplitude of the crystal is also directly proportional to the voltage applied to the crystal (1).

The crystal circuit was constructed for resonance at the natural frequency of the crystal as a parallel resonant circuit with a variable condenser and an inductance, which was coupled on the same axis with the inductance of the primary circuit. Because a high voltage was necessary for a large amplitude, and a high energy output was required, a high ratio of turns of the secondary circuit over the primary circuit was used. The primary circuit was the antenna-ground circuit.

Crystal and Mount

Several methods of mounting the crystal were tried. The location of the pressure of the contacts on the crystal, as well as the bedding of the crystal, were found to be important factors in the amount of damping of the vibrations. Clearly, a high pressure of the electrical contacts on the faces of the crystal damped the vibrations of the crystal to such a degree that they could not be detected at all. The measure of amplitude of vibration was the amount of rise (or fountain) of the oil directly over the crystal. It was also found that the amount of damping was greater when the contact

was in the center of the crystal, than when it was near the edge. Plastic, lead, oil and air backings for the crystal were tried; and it was found that the air-backed mounting supplied the vibrations of greatest amplitude.

The mounting used is shown in Figure 2. The crystal, which was in the shape of a circular disc, was held by two brass rings (B), which were held in place by two lucite blocks (C_1 and C_2). The air backing (A) was provided below the crystal. The liquid (L) to be vibrated is shown directly on the crystal. The glass tubing (G) over the brass rods (R_1 and R_2), which hold the lucite blocks together, prevented arcing over of the high-voltage current, which was carried in the two brass rods. The electrical contacts on the two faces of the crystal were provided by the brass rings, which were connected to the brass rods (R_1 and R_2). The entire crystal mount was submerged in insulating oil up to the level (O).

Experiments

Preliminary Experiments

When silt suspended in water in a test tube was exposed to the vibrations no visible change occurred. This may have been due to the fact that the vibrations not damped by the glass surface of the test tube were not sufficient to have an effect on the silt suspension.

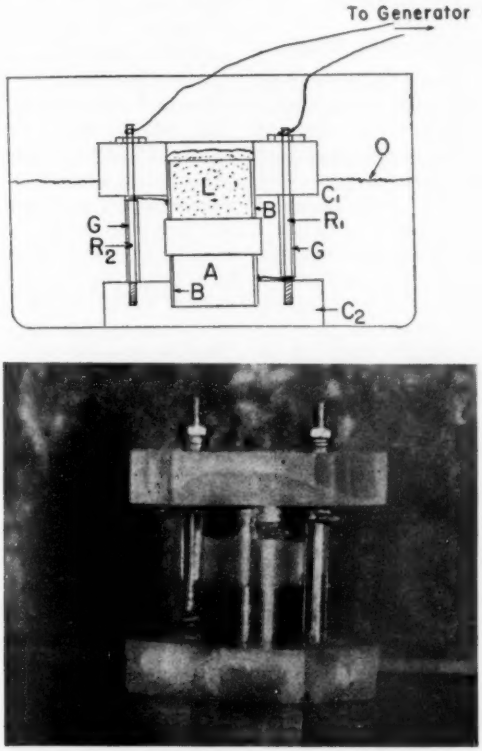


FIGURE 2.—Section through mount and crystal in oil bath, and view of assembled crystal mount.

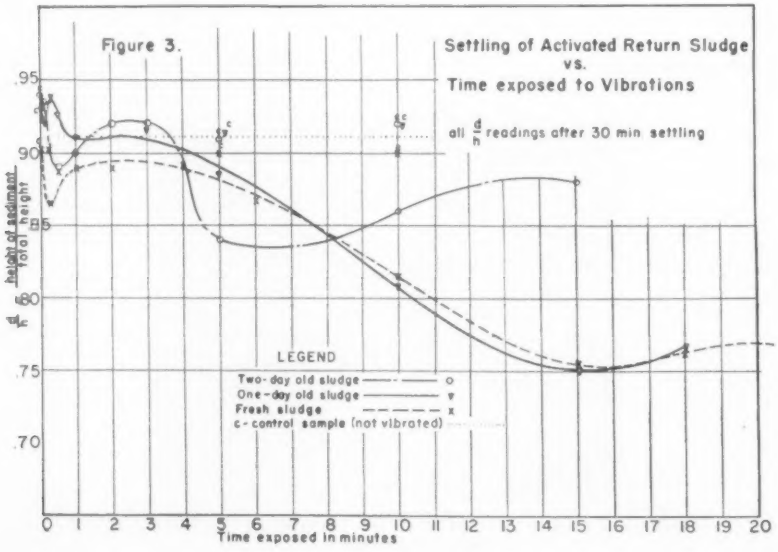
An alum solution, which was saturated at room temperature, was vibrated for 10 min. in a test tube and showed colloidal floc, which did not settle readily. A control sample showed no such flocculation.

Although these very brief experiments did not show promise of future application; the possible practical use of ultrasonics on these types of suspensions should not be excluded. Further research might produce promising and interesting results.

It was found that when return activated sludge was vibrated in the cavity directly above the crystal it settled much more rapidly after exposure than did a non-vibrated control sample. Hence, it was decided to study this phenomenon further.

Settling of Activated Return Sludge

The activated return sludge was secured from the activated return sludge line at the Back River sewage plant at Baltimore, Md. The sludge was kept fresh by bubbling air through it. This also kept the solids well dispersed throughout the container. The sludge was drawn off by a pipette, and a 7-ml. portion was put in the cavity above the crystal. The oscillator was turned on, and the length of exposure timed by a stop watch. After the oscillator was turned off, the liquid was drawn off with a wide-mouthed eyedropper in order to disturb the floc as little as possible. From the eyedropper the sludge was placed into a test tube, and (except where noted) after 30 minutes of settling the height of sediment, d, and the total height of the liquid, h, were marked off on the test tube and later measured with a scale. The results are shown as the ratio d/h (Figure 3). This ratio can be used as an index of the amount of settling, as shown by Kalinske (6). After about 4 min. of vibration in the cell, slow stirring could be observed in the sludge. This stirring increased in intensity gradually, and after about 5 min. coagulation of the solid particles could be seen. The smaller lumps remained in circulation, due to the stirring, while larger lumps remained at the surface.



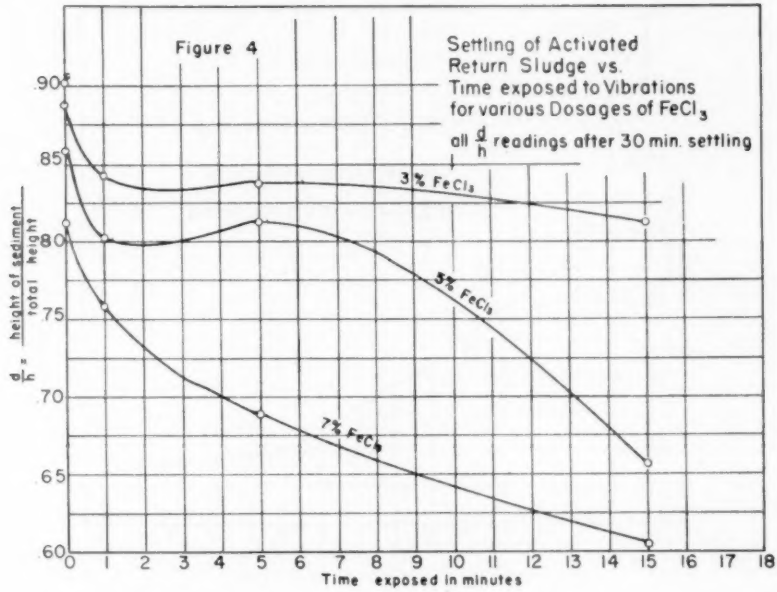


Figure 4
Settling of Activated Return Sludge vs. Time exposed to Vibrations for various Dosages of FeCl3
all d/h readings after 30 min. settling
3% FeCl3
5% FeCl3
7% FeCl3
d/h = height of sediment / total height
90
85
80
75
70
65
60
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Time exposed in minutes

This same effect was observed by Wood and Loomis (7), who stated that the coagulated particles must be driven to the surface by the radiation pressure of the vibrating crystal.

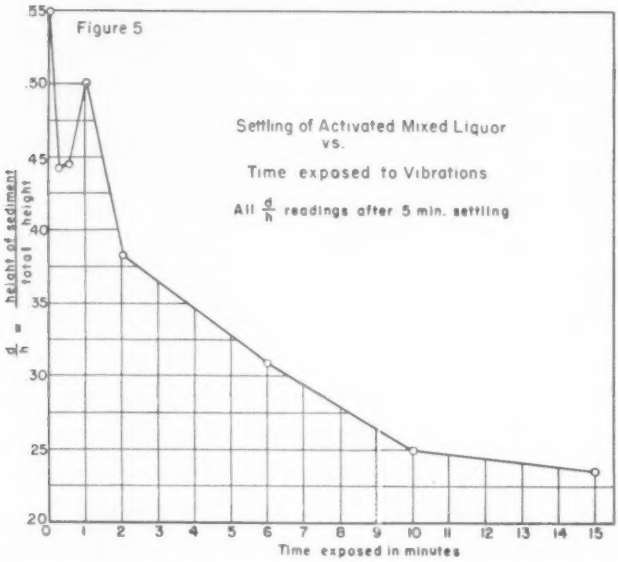
Since it was possible that the coagulating effect may have been due to the slow stirring alone; control samples were run in which samples of the sludge were exposed to slow stirring by an electrically driven stirrer. These controls showed no improved settling characteristics.

It was observed that the temperature of the crystal and the sample rose during vibration about 0.5° per minute. Control samples were exposed to the same temperature rise. No increased rate of settling was observed.

Control samples were run at the same time with every set of experiments. Some of the controls were taken from the sludge container and put directly into the test tube; others were put on the crystal and then put into the test tube, and were then observed for any possible effect which the eyedropper handling or the rest of the procedure might show. No effect was found.

Samples of activated return sludge, which were fresh, one day old, and two days old, were exposed to the same intensity of vibration at about 240 kc. for various periods of time. The results are shown in Figure 3. The exposure time-settling characteristics appeared similar in all three sludges.

There was distinct improvement in settling at some point during the 0 to 1-min. vibration period. In the period from 1 to 4 min. there was no improvement in settling. This may have been due to the fact that during the first minute there was no opportunity for the particles to be dispersed or torn apart, allowing a temporary coagulating effect. After 1 min. of exposure there was more dispersion, which transformed into better coagulation and clearing after 4 min. of exposure. It could be seen that up to the 4-min. point the characteristics of the 2-day and 1-day sludges were very similar.



The 2-day sludge reached its maximum degree of settling after 5 min. of vibration, whereas the 1-day sludge reached its maximum settling after 15 min. of vibration.

It should be noted here that the varying characteristics demonstrated by the sludges of different ages may have been partially due to factors other than age (that is, suspended solids, temperature, total solids, etc.) Inasmuch as the amount of dissolved oxygen in the solution is a consideration in the effect of ultrasonics, the varying amounts present in the sludges may have to some degree accounted for their varying settling characteristics. Of course, the age itself is one of the strongest reasons for the variability of the results. As pointed out by Imhoff and Fair (8), "Ordinarily, the fresher and stronger the sewage, the greater the settling efficiency."

After the 4-min. point the fresh sludge and the 1-day sludge assumed very similar characteristics and both reached their maximum degree of settling after 15-min. exposure.

Settling of Activated Return Sludge with Addition of $FeCl_3$

Samples of activated return sludge, to which 3, 5, and 7 per cent (of solids) of $FeCl_3$, respectively, have been added, were vibrated at 242.3 kc. The results are shown in Figure 4. There was rapid settling during the period from 0 to 1 min. After that period the rate of improvement of settling was not as high, but settling improved to a period of 15 min. of exposure and probably further. The higher the percentage of $FeCl_3$, the better was the degree of settling.

Settling of Activated Mixed Liquor

Samples of activated mixed liquor were vibrated. The results, as shown in Figure 5, exhibited the same characteristic shape of the curve as in the case of activated return sludge. The liquor was drawn directly from the aeration tank. Because it contained only 0.13 per cent total solids, and the settling was much more rapid, the d/h readings were taken after 5 min.

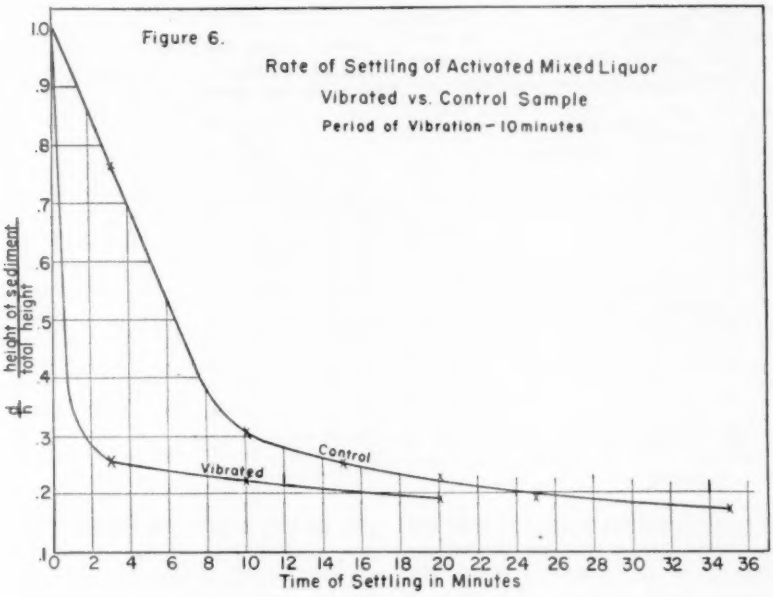


Figure 6.
Rate of Settling of Activated Mixed Liquor
Vibrated vs. Control Sample
Period of Vibration – 10 minutes
height of sediment / total height
Control
Vibrated
Time of Settling in Minutes

of settling instead of after 30 min. It was also noted that the supernatant liquid remained quite turbid and that the line of separation between the settled matter and the supernatant was not as distinct as in the activated return sludge. Again, the characteristic improvement in settling during the first minute of vibration was noted. In this case, the maximum settling during the first minute was reached after 15 sec. The point of maximum settling was again around 15 min.

Rate of Settling of Activated Mixed Liquor

The results of the experiment on rate of settling of activated mixed liquor (Figure 6) indicate that the rate of settling of the vibrated sample was a much higher one up to 3 min. of settling than that of the control. After 3 min. of settling the rate levels off. The sample used in this experiment was vibrated for 10 min.

Time for Equal Amounts of Settling for Vibrated and Control Samples

In answer to the question: "How much faster does the sludge settle when exposed to the vibration than the control?", an experiment was run to determine time for equal amounts of settling for vibrated and control samples. The results (Figure 7), plotted in terms of the ratio "time of settling of control/time of equal amount of settling of vibrated sample," indicated the increasing effectiveness of the vibrations with time. After 10 min. the rate of settling is doubled; and after 15 min. it is tripled.

Effect of Power Applied on the Crystal on the Degree of Settling

Because it was only possible to use a small amount of power (a maximum of about 30 watts) in this experiment, information on the effect of a variation in power was considered valuable.

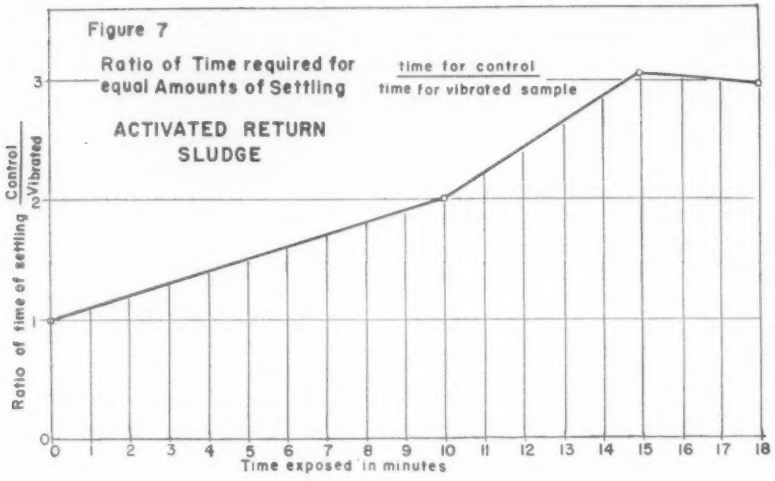
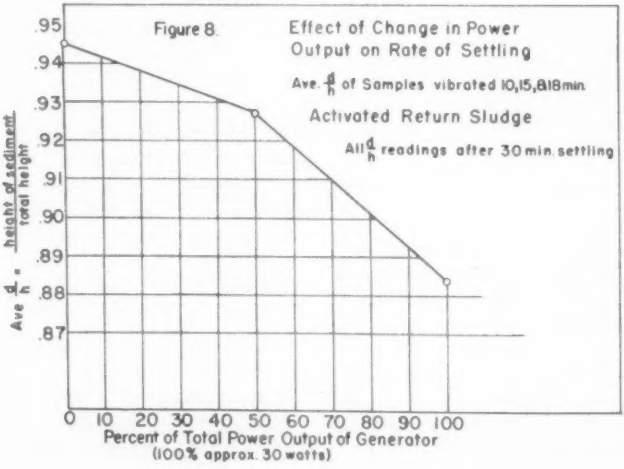


Figure 7
Ratio of Time required for equal Amounts of Settling
time for control / time for vibrated sample
ACTIVATED RETURN SLUDGE
Ratio of time of settling Control / Vibrated
0
1
2
3
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Time exposed in minutes

The only practical method of reducing the power was to decrease the voltage applied to the crystal. Since the voltages used were so high that no radio frequency voltmeter could be used directly, the change in voltage could only be approximated by placing one of the voltmeter leads near a point from which the radio frequency voltage was being radiated, in this case by the variable condenser. Samples of activated sludge were then vibrated at full voltage and half voltage for times of 10, 15, and 18 min., respectively. The results are shown in Figure 8. The values shown are the average d/h values for the various intensities of power. Results indicate that a small change in wattage had an effect on the rate of settling.



Conclusions

Ultrasonic vibrations were passed into activated return sludge and mixed liquor by means of a piezoelectric generator. The power output was on the order of 30 watts, the frequency between 238 and 242 kilocycles. The degree of settling after exposure to the vibrations was observed and compared with unvibrated control samples.

The activated return sludge and mixed liquor were found to settle more rapidly after exposure to the vibrations, each exhibiting a point of maximum degree of settling, which in most of the experiments occurred after a period of 15 min. of vibration. In addition to the improved settling, a slight increase in turbidity of the supernatant liquid, depending on the length of exposure, was observed.

Samples of activated return sludge settled twice as fast after 10 min. of vibration and three times as fast after 15 min. of vibration as did the control samples.

Samples to which 3, 5, and 7 per cent, respectively, of ferric chloride had been added, showed in that order progressively improved settling characteristics. The most rapid improvement was observed in the period from "no exposure" to 1 min. of exposure. The point of maximum settling was not found, but occurred on or after 15 min. of exposure.

An increase in power output of the generator showed a similar increase in the amount of settling, indicating that with increase in power output the time period required to reach the point of maximum settling can be shortened considerably.

Appendix

Theoretical Considerations

Sound waves are propagated in media having elasticity and inertia. How these waves propagate longitudinally can be seen by the ripples on a water surface onto which a stone has been dropped. Internally, sound waves progress by alternately producing zones of compression and of dilation perpendicular to their vector of progression. This could be visualized by a long flexible spiral spring, certain sections of which are constantly being compressed or pulled apart.

Sonic or ultrasonic energy in liquids is dispersed by three major phenomena (9):

1. Viscous friction due to relative motion of the intermediate layers.
2. Heat conduction from the compressed areas to the dilated areas.
3. Heat radiation from the compressed areas.

It is this relative motion within the liquid which appears to be the cause of the coagulation phenomena observed. "Spheres at rest in a vibrating medium repel one another if their line of centers is parallel to the vibration vector, but attract one another if their line of centers is normal to this direction. The force of attraction or repulsion varies inversely as the fourth power of the distance or the square of the velocity of the vibrating fluid. This attraction of particles is sufficient to account in a general way for the coagulation. This coagulation should vary with the square of the amplitude of vibration" (10).

Soellner and Bondy (11) describe the relationship between energy and coagulation. At low energy levels there is only coagulation. When more energy is used, both coagulation and emulsification occur. Dispersion and emulsion cannot be differentiated. The same authors also consider the forces causing coagulation as "radiation pressure" due to the diffraction of sound energy. They consider this radiation pressure the ultimate cause of the coagulation of ultrasonics. "These forces cause a kind of ortho-kinetic coagulation and when stationary waves occur build up zones of accumulation, which for several reasons favor coagulation." Colloids do not coagulate.

The dispersion and emulsification, as described by Soellner and Bondy, were also observed in these experiments in the resulting turbidity of the supernatant liquid, which increased with the length of exposure to the vibrations. This factor would, of course, be a disadvantage in the utilization of ultrasonics in sewage treatment. It is considered probable that upon further study frequencies, intensities, and rates of application could be found which would prevent this turbidity.

Practical Application

It is to be pointed out again that these experiments were carried out at only one frequency, with very low intensity of vibration, and using only one method of application of the vibrations to the liquid. It was shown that the rate of coagulation will increase with the power output—that is, amplitude—and it therefore lies within the realm of speculation that ultrasonic waves could be passed into a specially designed channel (opposite wall designed for resonance at the frequency used), through which water or sewage for treatment could be passed rapidly into a sedimentation basin of comparatively small size, in which rapid settling would occur.

The method of application used in this experiment was a very inefficient one. Much energy was lost between the power input and the crystal. These losses could be eliminated by the use of an ultrasonic siren or a Hartman generator. These types of generators could not hold a frequency as accurately as a piezoelectric generator, yet it can be shown that the frequency is not too critical in coagulation, if held within a reasonably narrow range.

Were a piezoelectric generator to be used, the energy could be more efficiently utilized by preventing too much radiation, and perhaps by using a crystal or an applicator having a concave shape similar to the concave crystal described by Gruetzmacher (12).

Other Uses in the Sanitary Engineering Field

Attention is drawn to an article by Beuthe, Furbach, and Soerensen (13) on "Water Purification by Ultrasonics." These experimenters noticed that tap water was made cloudy by the vibrations. They used a generator with a power output of 1.5 kw. at a frequency of 380 kc. They were able to remove carbonate hardness and found that the precipitate consisted of CaO and MgO. When the crystal was kept cool, this effect did not occur and it was therefore concluded that the effect was entirely due to the rise in temperature. Using what these authors describe as a 75 per cent saturated solution of $CaSO_4$, the reduction in turbidity from an unvibrated sample was measured. It was found, using an absorption-type turbidimeter, that the turbidity could be reduced by vibration in amounts proportional to the amount of dissolved oxygen in the water. By saturation with air and 2-hr. vibration, the turbidity was reduced from 100 per cent to 88.5 per cent; using oxygen the turbidity was reduced to 75 per cent, and with carbon dioxide the turbidity was reduced to 95 per cent. The authors also determined the amount of hydrogen peroxide produced by a given amount of power. This turned out to be 0.10 watts per gram $= 18.2 \times 10^{-5}$ grams of H_2O_2 per 50 grams of H_2O.

Ultrasonics is also known to have a bactericidal and a viricidal effect, as well as a destructive effect on small animals and plants. There is much discussion concerning the cause of these phenomena. They may be due to the strong dispersive power, the oxidizing effect, the cavitation, thermal changes, or the formation of hydrogen peroxide.

The effect of sonic vibrations of vari-

ous lengths of exposure in the inactivation of several types of bacteria by dispersion is discussed by Shropshire (14).

Ultrasonics has already found application in some branches of sanitary engineering. It is being applied in the precipitation of industrial smokes and the homogenization of milk. Further research may show that its applications in the sanitary engineering field have far greater possibilities than heretofore expected.

Acknowledgments

The research described herein was performed as a part of the author's graduate work at the Johns Hopkins University. Thanks go to Dr. Abel Wolman for suggesting the study, to Dr. J. C. Hubbard for guidance and advice in ultrasonics techniques, to Dr. C. E. Renn for his advice and suggestions, and to G. V. Levin, who shared a sanitary engineer's struggle with the electron in the design and construction of the apparatus.

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CORRECTION

In the announcement of availability of the Ohio River Valley Water Sanitation Commission booklet on "Bacterial-Quality Objectives for the Ohio River" (THIS JOURNAL, **23**, 7, 860; July, 1951), the maximum permissible monthly arithmetical average M.P.N. of coliforms in bathing or swimming waters, given as "1,000 per ml.," should read "1,000 per 100 ml."

DESIGN OF PALMER-BOWLUS FLUMES

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The Palmer-Bowlus flume or meter, developed in 1936 (1), is an adaptation of the Venturi flume for use in sewers. The Palmer-Bowlus (or "P-B") meter differs from the usual Venturi flume principally in that the P-B meter requires no drop along its bottom profile. Therefore, it may be installed in existing sewers where invert elevations cannot be changed. Also, the P-B meter incorporates a maximum of streamlining to minimize head losses and obstructions to the passage of floating or other suspended solids.

Since 1936 many P-B meter installations have been made, principally in California. These installations have demonstrated the practicability of the device. However, it is believed that the P-B meter would be more generally used if the necessary design criteria were made more readily available to sewage works designers in compact and simplified form.

The present discussion describes a design procedure, developed in the authors' offices, which is applicable to most of the sewer flow measurements ordinarily encountered. The procedure comprises three steps:

1. Selecting the meter shape or proportions.
2. Rating the meter.
3. Laying out the pattern needed for constructing the meter.

Notation

The following letter symbols are used throughout this paper:

A = area of flow section (A_n, A_u, A_c), in square feet;

b = base width of throat, in feet;

B_c = width of water surface in throat, in feet;

d = depth of flow, in feet;

d_c = critical depth of flow in throat, in feet;

d_{cp} = critical depth of flow in sewer, in feet;

d_n = Normal depth of flow in sewer, in feet;

d_u = Depth of flow in sewer upstream from throat, in feet;

D = diameter of sewer, in feet;

E = energy of flow (E_c, E_u), in feet;

h_v = velocity head (h_{vu}, h_{vc}), in feet;

m = slope of side of throat;

p = slope of bottom sill transition;

Q = flow, in cubic feet per second;

t = height of bottom sill, in feet;

V = velocity of flow, in feet per second;

y = ratio d_c/b; and

z = ratio d_c/D.

Meter Description

As illustrated in Figure 1, the P-B meter comprises a control section or throat, plus upstream and downstream transition sections. The restriction caused by the control section results in backup above the meter, so that the depth of flow immediately above the meter, d_u, is greater than the normal depth, d_n. The upstream depth, d_u, is the depth actually measured, and the problem of calibrating the meter amounts to correlating values of d_u and Q.

1. Factors Controlling Design

The depth and velocity of flow are the factors which determine the applicability of the meter to an existing

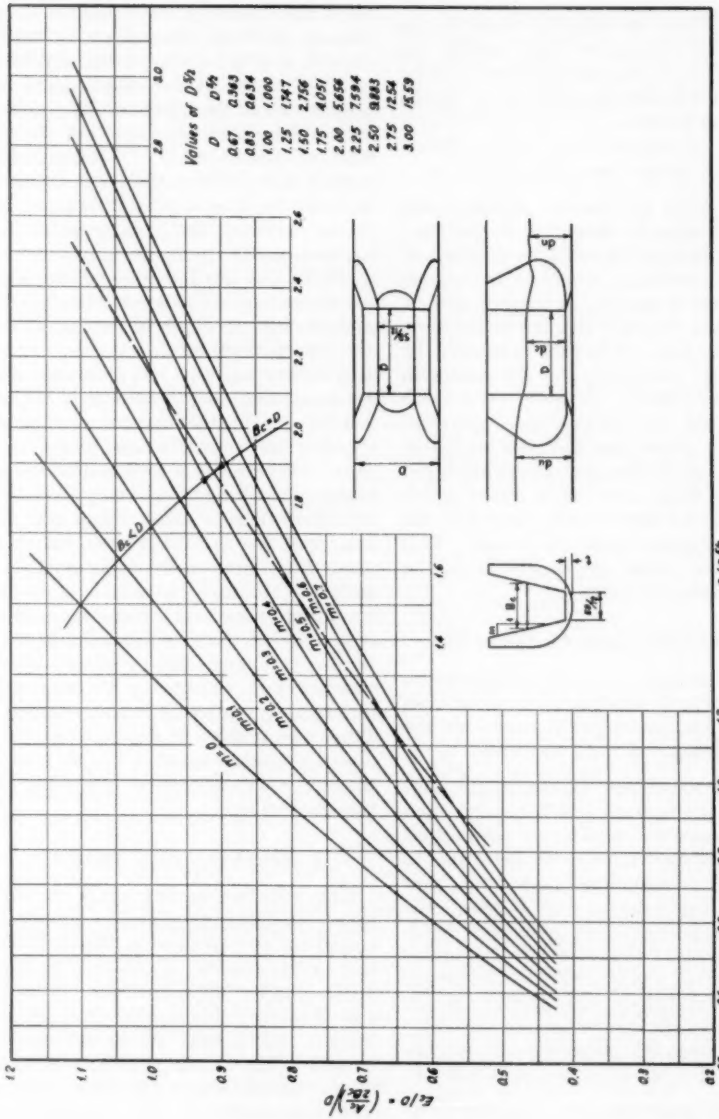

FIGURE 1.—Discharge—Total energy curves for flow in trapezoidal channels of varying side slope.

sewer; that is, they limit the proportions or shapes which may be selected for the control section, as follows:

(*a*) When the velocity of flow in the sewer is no more than enough to transport the suspended solids (that is, 2.0 to 2.5 ft. per sec.), the design should back up the flow as little as necessary, in order to maintain as high a velocity as possible upstream from the meter.

(*b*) When the velocity of flow in the sewer is greater than 2.5 ft. per sec., the proportioning could be determined by the condition stated in (*a*) above; however, a greater restriction can be provided without causing deposition, and in most instances this will be desirable. In these cases the maximum upstream depth is limited to a value such that (1) the minimum upstream velocity is not less than 1.8 to 2.0 ft. per sec. or (2) the upstream depth is not greater than some depth above which undesirable flow conditions result and measurement becomes uncertain. This limit has been set at $0.85D$ in the discussion to follow.

2. Limiting Cases for Meter Use

The limiting range of usefulness of a P-B meter*—that is, the measurable maximum discharge—depends on the normal depth of flow, as follows:

(*a*) Palmer and Bowlus state that for proper operation of the meter such that possible backwater conditions downstream from the throat (due to channel irregularities) are not projected upstream so as to affect the rating qualities of the meter, the depth downstream from the meter should not be greater than $0.90\ d_u$. However, where conditions will allow, it is advisable to allow more drop in the water surface than this minimum amount, say a drop of $d_u/6$, which results in a downstream depth equal to $0.833\ d_u$. If the depth upstream from the meter is limited to a maximum of $0.85D$, as stipulated in Section 1(*b*), and the drop allowed through the meter is $d_u/6$, then d_u may not exceed $0.833 \times 0.85D = 0.71D$. For a downstream depth of 90 per cent of the upstream depth, the normal flow in the pipe may not exceed $0.90 \times 0.85D = 0.76D$. When the normal flow depth in the sewer exceeds these limits, special provisions must be made in order for a P-B meter to measure such extreme flows.

(*b*) In the usual flow condition encountered, velocities are relatively low and the normal depth of flow is above the critical depth of flow for the quantity of flow and pipe size involved. In all cases where depth of flow is above critical depth, the maximum normal depth is limited as discussed in Section 2(*a*). However, in sewers laid on steep slopes, "shooting flow" may occur—that is, the normal depth of flow may be less than the critical depth. In this case, the flume restriction must be sufficient to cause a hydraulic jump to form far enough upstream from the meter so that the turbulence due to the jump is damped to the extent that tranquil flow conditions are attained immediately upstream from the meter. When this problem is encountered, the design procedure must be modified in a manner which is beyond the scope of this discussion.

3. Shape of Control Section

The selection of the shape of the throat section is governed by practical considerations involved in the installation of the meter, as well as by the depth-velocity relationships. Palmer and Bowlus recommend a trapezoidal section, which may be varied as to bottom width, side slope, and the height of the bottom above the pipe invert. The experience of the authors in installing P-B meters has emphasized the desirability of a design that can be readily and yet accurately built by the

* Investigations are now being conducted by the Civil Engineering Division, University of California, to determine by testing the precise limits of applicability of a given P-B meter installation.

contractor. The best method of installation for small meters is to prefabricate the entire throat and transition sections of sheet metal. The prefabricated meter is then grouted into the sewer section. This technique insures accurate construction of the meter; the only important field precaution is to install the meter with the bottom of the throat section level transversely and with the desired bottom height.

The physical limits of such prefabrication restrict the bottom width of the control section to about $5D/12$ when the bottom of the control section is placed at a distance $D/12$ above the pipe invert. Other heights of the bottom sill with corresponding base widths may be selected, but the above proportions have ordinarily been found to be satisfactory and will be assumed in the discussion to follow. Based on the assumptions that the bottom height of the throat equals $D/12$ and base width equals $5D/12$, the problem in the selection of a meter resolves itself to the determination of the side slopes of the control section which will satisfy the criteria discussed in Sections 1 and 2. Moreover, Palmer and Bowlus recommend that the length of the throat section be at least equal to the pipe diameter, and that the transitions upstream and downstream be sloped a minimum of approximately one laterally to three longitudinally.

4. Derivation of Formulas

In the design of a meter for low velocities, as discussed in Section 2(*a*), the depth downstream from the meter for all practical considerations can be considered equal to the normal depth of flow in the sewer without the meter, and is designated as d_n. The area of the water section, the velocity, and the velocity head for this condition are A_n, V_n, and h_{vn}, respectively. Similarly, the properties upstream are designated as d_u, A_u, V_u, and h_{vu}. The energy upstream from the meter is

$$E_u = d_u + h_{vu}.$$

When the upstream depth is such that the drop in the water surface through the meter is one-sixth of the upstream depth, $d_u = 1.20 d_n$ and the total energy of flow upstream is

$$E_u = d_u + h_{vu} = 1.20\, d_n + h_{vu}.$$

If the height of control above the pipe invert equals t, the energy in the throat section in terms of the properties upstream, assuming negligible hydraulic losses between the two sections, is

$$E_c = d_u + h_{vu} - t,$$

or, in terms of the downstream depth,

$$E_c = 1.20\, d_n + h_{vu} - t.$$

Based on the properties of the control section, where the flow is at critical depth, the energy in the throat is

$$E_c = d_c + h_{vc} = d_c + A_c/(2B_c)$$

where d_c, h_{vc}, A_c, and B_c are, respectively, the critical depth, the velocity head, the area, and the width of water surface corresponding to the critical depth. Equating the values of E_c gives

$$\begin{aligned} E_c &= d_c + A_c/(2B_c) \\ &= d_u + h_{vu} - t \quad . . (1) \end{aligned}$$

Dividing by D, setting $z = d_c/D$, and letting $t = D/12$ gives

$$\begin{aligned} E_c/D &= z + \frac{A_c/(2B_c)}{D} \\ &= d_u/D + h_{vu}/D - t/D \\ &= d_u/D + h_{vu}/D - 1/12 \quad . . (2) \end{aligned}$$

In selecting the proportions of a control section, it is usually found that if the control section is properly proportioned for the maximum anticipated flow, the meter will function properly throughout the entire range of flow. Hence, to select the meter proportions it is necessary to determine the dimensions of a throat which will satisfy Eq. 2 when the flow is at maximum, keeping in mind that the quantities d_c and z must in addition satisfy the well-

TABLE I.—Discharge—Total Energy Data for Flow in Trapezoidal Sections of Varying Side Slopes

$m=0$		$m=0.1$		$m=0.2$		$m=0.3$	
$Q_c/D^{5/2}$	E_c/D	$Q_c/D^{5/2}$	E_c/D	$Q_c/D^{5/2}$	E_c/D	$Q_c/D^{5/2}$	E_c/D
0.389	0.45	0.404	0.441	0.419	0.433	0.437	0.428
0.599	0.60	0.629	0.584	0.661	0.572	0.698	0.563
0.836	0.75	0.890	0.726	0.950	0.710	1.010	0.697
1.100	0.90	1.185	0.866	1.280	0.846	1.380	0.830
1.389	1.05	1.521	1.006	1.660	0.980	1.810	0.962
1.692	1.20	1.871	1.144	2.075	1.114	2.280	1.094
$m=0.4$		$m=0.5$		$m=0.6$		$m=0.7$	
$Q_c/D^{5/2}$	E_c/D	$Q_c/D^{5/2}$	E_c/D	$Q_c/D^{5/2}$	E_c/D	$Q_c/D^{5/2}$	E_c/D
0.453	0.423	0.470	0.419	0.488	0.415	0.506	0.412
0.734	0.557	0.770	0.551	0.807	0.546	0.846	0.543
1.078	0.689	1.141	0.682	1.216	0.679	1.325	0.690
1.481	0.820	1.59	0.814	1.760	0.829	1.886	0.840
1.960	0.950	2.18	0.964	2.365	0.979	2.51	0.990
2.560	1.093	2.83	1.114	3.030	1.129	3.18	1.140

Values above heavy line are for trapezoidal section with $B_c < D$; values below line are for section with lower portion a trapezoid and upper portion a rectangle with $B_c = D$.

known general criterion for critical flow,

$$A_c^3/B_c = Q^2/g.$$

The last equation, when expressed for a trapezoidal channel of bottom width b and side slopes m, reduces to

$$\frac{Q}{b^{5/2}} = \sqrt{\frac{g\,y^3\,(1+m\,y)^3}{(1+2m\,y)}} \quad \ldots\ldots(3)$$

Reducing further and letting $b = 5/12\ D$ and $z = d_c/D$,

$$\frac{Q}{D^{5/2}} = \frac{5}{12}\sqrt{\frac{g\,z^3\,(1+2.4m\,z)^3}{(1+4.8m\,z)}} \quad \ldots(4)$$

Also, from the properties of a trapezoidal section of base width $5D/12$ and side slopes m,

$$\frac{E_c}{D} = z + \frac{A_c/(2B_c)}{D}$$

$$= z + \frac{z}{2}\left(\frac{5/12 + z\,m}{5/12 + 2z\,m}\right) \quad \ldots(5)$$

Equations 4 and 5 have been solved simultaneously for various values of m with the elimination of the factor z by using z as a parameter. The results are plotted in Figure 1, with values of $Q/D^{5/2}$ as abscissas and E_c/D as ordinates. Table I summarizes the data used for plotting Figure 1.

In using Figure 1, the quantity E_c/D is computed by use of Eq. 2. It is noted that the use of Figure 1 to obtain the proper side slopes requires that the base of the control section have a width of $5D/12$. However, the curves are applicable for any desired bottom sill height t or for any drop of water surface through the meter.

5. Selection of Throat Section

Determination of the side slopes of a throat section of base width $5D/12$ and bottom height $D/12$, is accomplished by the following procedure:

(*a*) For the given sewer diameter, sewer slope, and design or maximum discharge, determine V_n, A_n, and d_n.

(*b*) Determine the quantity $Q/D^{5/2}$.

(*c*) Determine the quantity E_c/D (Eq. 2) for one of the following conditions:

1. When $V_n < 2.0$ to 2.5 ft. per sec., determine $d_u = 1.20\ d_n$ and the corresponding values of A_u, V_u, and h_{vu} for the maximum Q.
2. When $V_n > 2.0$ to 2.5 ft. per sec., determine d_{cp} for the given Q and D. If $d_n > d_{cp}$, proceed as in (*a*) above, or determine the value of d_u for a desired minimum upstream velocity (usually 1.8 to 2.0 ft. per sec.) or a maximum upstream depth of $0.85D$. For the chosen value of d_u determine the corresponding values of A_u, V_u, and h_{vu} for the design Q. If $d_n < d_{cp}$, special consideration must be given to insure a hydraulic jump upstream from the meter. Design criteria for this condition are not presented.

(*d*) With the computed values of $Q/D^{5/2}$ and E_c/D, enter Figure 1 and select the proper value of m.

6. Rating the Meter

After the flume has been constructed and installed, the properties of the control section (specifically, b, m, and t) are measured. The meter is then rated using these dimensions, which of course may vary slightly from the design values.

A common procedure for rating is the trial and error procedure—that is, arbitrarily to assume values of the critical depth d_c in the control section, then compute $h_{vc} = A_c/(2B_c)$, V_c, $Q_c = A_c V_c$, and $E_c = d_c + h_{vc}$. Then for each value of Q_c and E_c the value of d_u is determined so that $d_u + h_{vu} = E_c + t$. This solution may be made by trial by assuming values of d_u until the correct value is obtained, or by the use of an Arredi diagram which is a general graphical solution of the above relationship, or by the semi-graphical method for circular sections proposed by Palmer and Bowlus (1).

The trial method is simplified through use of Figure 2, which is a graphical solution for a U-shaped section. (U-shaped sections are commonly employed where it is possible to break away the top of the sewer so as to form vertical side walls above the mid-depth level of the sewer.) To obtain the proper value of d_u in terms of d_u/D, Figure 2 is used by entering the diagram with $Q/D^{5/2}$ as the abscissa and E/D as the ordinate, where Q and E are, respectively, Q_c and E_c for the throat section. The rating curve is then obtained by plotting d_u *versus* Q. Table II summarizes the data used to plot Figure 2.

7. Layout of Pattern

To insure that the flow both upstream and downstream from the control section is streamlined, it is necessary to develop a pattern for the sides or wall wings and for the sloping base or sill. Figure 3 illustrates a simple semigraphical method of determining such patterns. The angle between the side of the control section and the wing section has been set so that a contour is deflected an amount of 1 laterally to 3 longitudinally, with the result that the true slope of the wing is $2m\sqrt{2}/3 = 0.943m$. To determine the patterns proceed as follows:

(*a*) Draw a transverse section through the meter showing both the pipe and the throat section. Draw thereon contours of depth below the top of the meter section.

(*b*) Draw a plan of the side of the throat and sill, laying out contours to scale (projected from transverse section of throat if desired).

(*c*) Deflect the contours an amount equal to 1 on 3, and extend.

(*d*) Determine points b, c, d, e, f, g, and h by intersection of deflected contours with projections from the corresponding points b' to h' on the circular pipe from the transverse section.

(*e*) Project points a to i normal to the deflected contours, and lay off lengths equal to $h\sqrt{1 + (0.943m)^2}$ below some base line $O - O$.

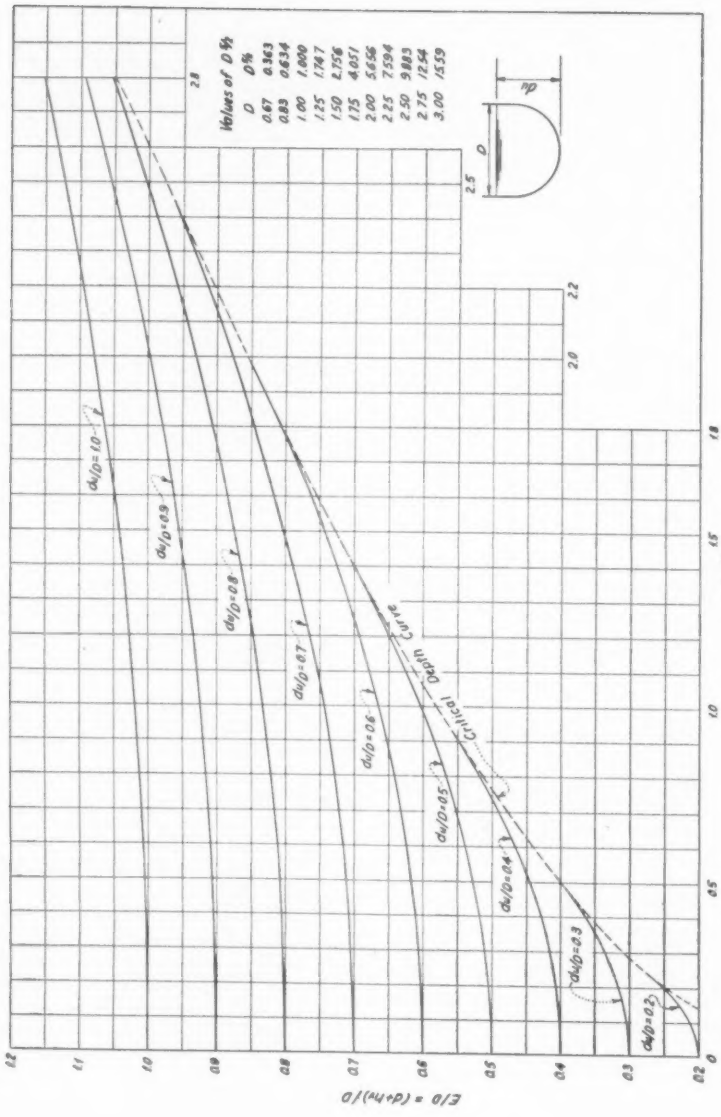

FIGURE 2.—Discharge—Total energy curves for flow in U-shaped channels.

TABLE II.—Discharge—Total Energy Curves for Flow in U-Shaped Channels
$E/D = d/D + h_v/D$

$Q/D^{5/2}$	$\frac{d}{D}$=0.1	$\frac{d}{D}$=0.2	$\frac{d}{D}$=0.3	$\frac{d}{D}$=0.4	$\frac{d}{D}$=0.5	$\frac{d}{D}$=0.6	$\frac{d}{D}$=0.7	$\frac{d}{D}$=0.8	$\frac{d}{D}$=0.9	$\frac{d}{D}$=1.0
0	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
0.05	0.123	—	—	—	—	—	—	—	—	—
0.060	0.134[1]	—	—	—	—	—	—	—	—	—
0.10	—	0.212	—	—	—	—	—	—	—	—
0.20	—	0.250	0.316	—	—	—	—	—	—	—
0.237	—	0.270[1]	—	—	—	—	—	—	—	—
0.30	—	—	—	0.416	—	—	—	—	—	—
0.40	—	—	0.363	—	0.516	0.610	0.707	0.805	0.904	1.003
0.522	—	—	0.408[1]	—	—	—	—	—	—	—
0.60	—	—	—	0.465	—	—	—	—	—	—
0.80	—	—	—	—	0.565	0.641	0.728	0.821	0.916	1.012
0.90	—	—	—	0.546	—	—	—	—	—	—
0.910	—	—	—	0.550[1]	—	—	—	—	—	—
1.20	—	—	—	—	0.646	0.693	0.764	0.847	0.935	1.028
1.40	—	—	—	—	0.696[1]	—	—	—	—	—
1.60	—	—	—	—	—	0.764	0.813	0.883	0.963	1.050
1.977	—	—	—	—	—	0.851[1]	—	—	—	—
2.00	—	—	—	—	—	—	0.877	0.930	0.998	1.078
2.40	—	—	—	—	—	—	0.955	0.987	1.043	1.112
2.666	—	—	—	—	—	—	1.020[1]	—	—	—
2.80	—	—	—	—	—	—	—	1.054	1.094	1.153

[1] $Q/D^{5/2}$ and E/D corresponding to critical depth.

(*f*) Connect the points so determined to produce the true pattern.

(*g*) Repeat steps (*b*) and (*e*) to prepare the sill pattern.

8. Examples of Throat Selection

(*a*) Assume $D = 12$ in. or 1.0 ft., $Q = 1.08$ cu. ft. per sec., and $V_n = 2.0$ ft. per sec. $A_n = Q/V_n = 0.54$ sq. ft., $A_n/D^2 = 0.54$ (enter a table such as Table 100, p. 299, King's "Handbook of Hydraulics" 3rd Edition). $d_n/D = 0.65$, $d_n = 0.65$ ft., and $Q/D^{5/2} = 1.08$. According to Section 5(*c*)1, $d_u = 1.20\, d_n = 1.2(0.65) = 0.78$ ft., from which $d_u/D = 0.78$, and $A_u = 0.657\, D^2$ (Table 100, King's "Handbook"). Therefore, $A_u = 0.657$ sq. ft., $V_u = Q/A_u = 1.64$ ft. per sec., and $h_{vu} = V_u^2/2g = 0.042$ ft., $E_c/D = d_u/D + h_{vu}/D - 1/12 = 0.780 + 0.042 - 0.083 = 0.739$. From Figure 1, $m = 0.26$.

(*b*) Assume $D = 12$ in. or 1.0 ft., $Q = 1.18$ cu. ft. per sec., $V_n = 3.0$ ft. per sec. Then $A_n = 1.18/3.0 = 0.393$ sq. ft., $A_n/D^2 = 0.393$, and $d_n/D = 0.50$, $d_n = 0.50$ ft., and $Q/D^{5/2} = 1.18$. Following Section 5(*c*)2, compute the critical depth, d_{cp}. (Enter a table such as Table 130, p. 441, King's "Handbook of Hydraulics.") For $Q/D^{5/2} = 1.18$, $d_{cp}/D = 0.458$ and $d_{cp} = 0.458$ ft. Since $d_n > d_{cp}$ proceed according to Section 5(*c*)1: $d_u = 1.20\, d_n = 0.60$ ft., $d_u/D = 0.60$, and $A_u = 0.492\, D^2 = 0.492$ sq. ft., $V_u = Q/A_u = 2.40$ ft. per sec., and $h_{vu} = 0.090$ ft. Also, $E_c/D = d_u/D + h_{vu}/D - 1/12 = 0.60 + 0.090 - 0.083 = 0.607$.

From Figure 1, $m > 0.7$. As additional depth is available upstream, investigate the criterion discussed in Section 5(*c*)2.

According to Subsection 5(*c*)2, try $V_u = 2.0$ ft. per sec. Then $A_u = 1.18/2.0 = 0.59$ sq. ft., $A_u/D^2 = 0.590$, $d_u/D = 0.703$ ft., $d_u = 0.703$ ft., and $h_{vu} = 0.062$ ft. Also, $E_c/D = d_u/D + h_{vu}/$

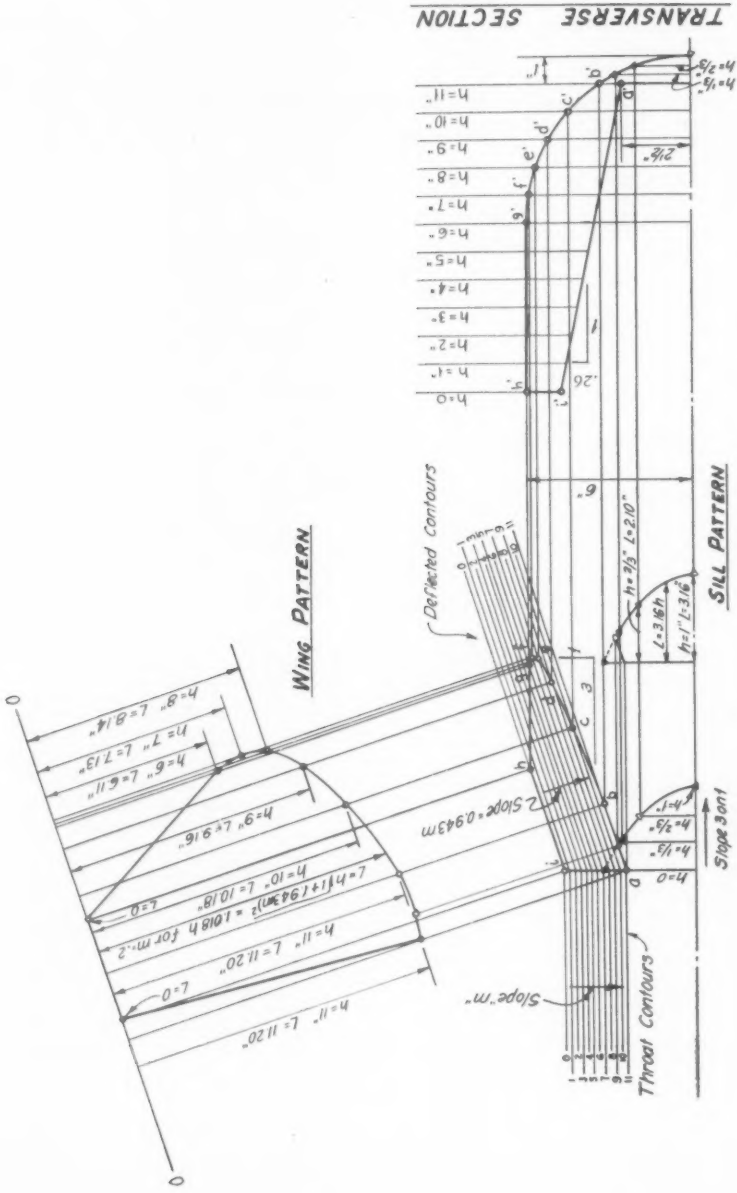

FIGURE 3.—Pattern development for P-B meter transition sections.

$D - 1/12 = 0.703 + 0.062 - 0.083 = 0.682$. From Figure 1, $m = 0.54$.

Further according to Section 5(*c*)2, try $V_u = 1.8$ ft. per sec. Then $A_u = 1.18/1.80 = 0.656$ sq. ft., $A_u/D^2 = 0.656$, $d_u/D = 0.778$, $d_u = 0.778$ ft., and $h_{vu} = 0.051$ ft., $E_c/D = d_u/D + h_{vu}/D - 1/12 = 0.778 + 0.051 - 0.083 = 0.746$ ft. From Figure 1, $m = 0.33$. Therefore, a value of m from 0.33 to 0.54 is indicated, depending on the desired upstream velocity.

(*c*) Assume $D = 12$ in. or 1.0 ft., $Q = 1.54$ cu. ft. per sec., and $V_n = 3.5$ ft. per sec. Then $A_n = 1.54/3.5 = 0.440$ sq. ft., $A_n/D^2 = 0.440$, $d_n/D = 0.547$, $d_n = 0.547$ ft., and $Q/D^{5/2} = 1.54$. Following Section 5(*c*)2, investigate the critical depth. Thus, $d_{cp}/D = 0.526$ and $d_{cp} = 0.526$ ft. Since $d_n > d_{cp}$, proceed according to Section 5(*c*)2. Try $V_u = 2.0$ ft. per sec., so that $A_u = 1.54/2.0 = 0.77$ sq. ft., and $A_u/D^2 = 0.77$. Then $d_u/D = 0.948$ and $d_u = 0.948$ ft. Since $d_u > 0.85D$, use $d_u/D = 0.85$, $d_u = 0.85$ ft. Then $A_u/D^2 = 0.712$, $A_u = 0.712$ sq. ft., $V_u = 2.16$ ft. per sec., $h_{vu} = 0.073$ ft., and $d_u/D + h_{vu}/D - 1/12 = 0.850 + 0.073 - 0.083 = 0.840$. From Figure 1, $m = 0.39$.

(*d*) Assume $D = 12$ in. or 1.0 ft., $Q = 1.96$ cu. ft. per sec., and $V_n = 5.0$ ft. per sec. Then $A_n = 1.96/5.0 = 0.393$ sq. ft., $A_n/D^2 = 0.393$, $d_n/D = 0.50$, $d_n = 0.50$ ft., $Q/D^{5/2} = 1.96$, $d_{cp}/D = 0.597$, and $d_{cp} = 0.597$ ft. Since $d_n < d_{cp}$, the flow is supercritical and special considerations are necessary which are beyond the scope of this discussion.

9. Sample Calculation for Rating Curve

Assume a meter for a 12 in. diameter pipe with the throat base width $5D/12$

TABLE III.—Illustration of Calculations for Rating Meter (Part A)

d_c	B_c	A_c	$h_{vc} = \frac{A_c}{2B_c}$	V_c	Q_c	$E_c = d_c + h_{vc}$	$E_c + 0.083$
0.1	0.469	0.0443	0.047	1.74	0.077	0.147	0.230
0.2	0.521	0.0938	0.090	2.40	0.225	0.290	0.373
0.3	0.573	0.1485	0.130	2.89	0.430	0.430	0.513
0.4	0.625	0.2084	0.167	3.27	0.682	0.567	0.650
0.5	0.677	0.2735	0.202	3.61	0.986	0.702	0.785
0.6	0.729	0.3438	0.236	3.90	1.340	0.836	0.919

TABLE IV.—Illustration of Calculations for Rating Meter (Part B)

Q^*	d_u/D (Fig. 2)	d_u/D†	d_u	A/D^2	A	V_u	H_{vu}	E_u	$E_c + 0.083$*	Remarks
0.077	0.22	—	0.22	0.128	0.128	0.60	0.006	0.226	0.230	—
	—	0.225	0.225	0.132	0.132	0.58	0.005	0.230	0.230	O.K.
0.225	0.36	—	0.36	0.255	0.255	0.88	0.012	0.372	0.373	—
	—	0.361	0.361	0.255	0.255	0.88	0.012	0.373	0.373	O.K.
0.430	0.49	—	0.49	0.383	0.383	1.12	0.020	0.510	0.513	—
	—	0.494	0.494	0.387	0.387	1.11	0.019	0.513	0.513	O.K.
0.682	0.62	—	0.62	0.513	0.513	1.33	0.028	0.648	0.650	—
	—	0.623	0.623	0.516	0.516	1.32	0.027	0.650	0.650	O.K.
0.986	0.75	—	0.75	0.643	0.643	1.53	0.036	0.786	0.785	—
	—	0.748	0.748	0.641	0.641	1.54	0.037	0.785	0.785	O.K.
1.340	0.87	—	0.870	0.763	0.763	1.76	0.048	0.918	0.919	—
	—	0.871	0.871	0.764	0.764	1.75	0.048	0.919	0.919	O.K.

* Values of Q_c and $(E_c + 0.083)$ from Table III.

† More accurate estimate of d_u/D based on results of value initially obtained from use of Figure 2.

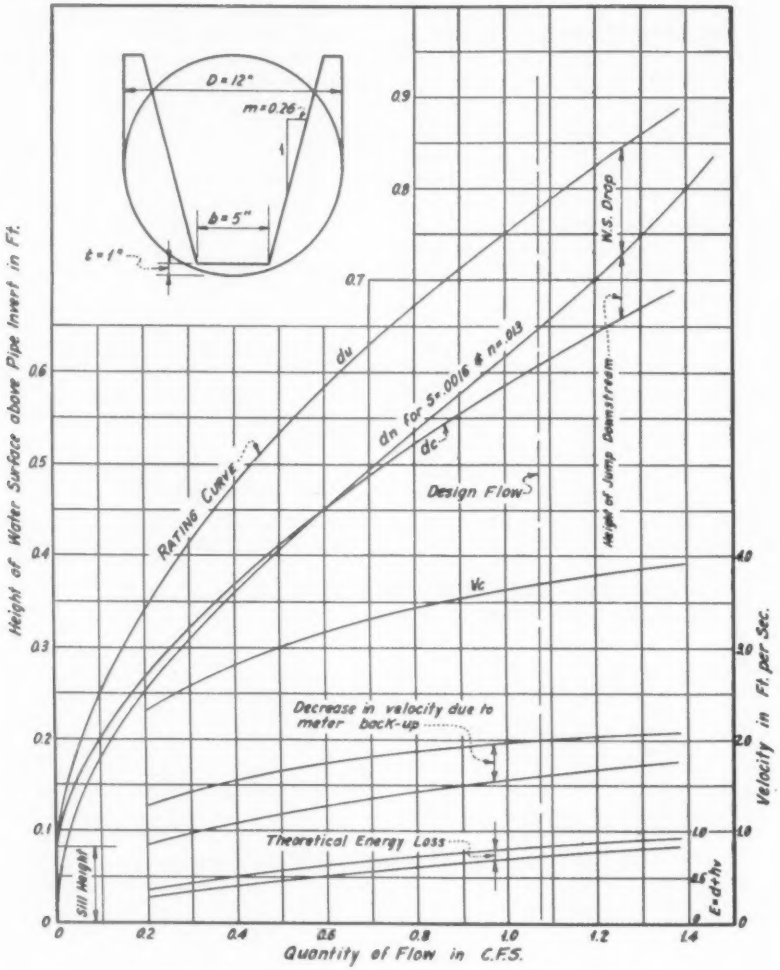

FIGURE 4.—Rating curve and depth, velocity, and energy curves.

= 5 in., height of sill $D/12 = 1$ in., and side slope $m = 0.26$ (Example given in Section 8(*a*) above.) $B_c = b + 2m\,d_c = 0.417 + 0.52\,d_c$, $A_c = d_c\,(b + m\,d_c) = d_c\,(0.417 + 0.26\,d_c)$.

Prepare calculations as illustrated in Tables III and IV.

The final values of d_u are plotted as ordinates with corresponding values of Q as abscissas (Figure 4) to produce the final rating curve. Other characteristics of flow for both the meter throat and upstream **U** section for this particular problem have also been plotted in Figure 4.

10. Summary

A procedure has been described to facilitate the design of Palmer-Bowlus

meters for installation in sewers where no drop in the invert grade is permissible.

The procedure involves three steps, as follows:

1. Selecting the proper shape of the trapezoidal control section; that is, determining the proper slope of the side walls.
2. Rating the meter, by a simplified trial and error method employing a graphical aid.
3. Laying out the pattern of the meter, employing a simple semigraphical technique.

Examples are given to illustrate the procedure.

Reference

1. Palmer, H. K., and Bowlus, F. D., "Adaptation of Venturi Flumes to Flow Measurements in Conduits." *Trans.*, A.S.C.E., **101**, 1195 (1936).

SEWER SERVICE CHARGES

At least 278 U. S. cities over 10,000 population have sewer service charges, according to "The Municipal Year Book–1951," published by the International City Managers' Association, Chicago, Ill. Of this number, 7 are cities of more than 500,000, and 5 adopted the charges during 1950.

In order of popularity, the bases of charges were metered water consumption, fixed percentage of the water bill, uniform rate, number of plumbing fixtures, and number of sewer connections.

Adoption of sewer service charges in 1950 was reported by 23 cities between 5,000 and 10,000 population. For residential service, 9 of the 23 cities base charges on a fixed percentage of the water bill, 8 on a flat rate, 4 on metered water consumption, and 1 each on the number of plumbing fixtures and the number of sewer line connections.

The charges reported are only the periodical charges to the users of a sewer system, based on the extent of use of the system. Not included are special assessments for sewer connections, tapping, or service charges for sewer connections, or property taxes earmarked for sewerage purposes

Revenues from the sewer service charges generally are earmarked for operation, management, maintenance, and repair of sewer systems and treatment plants, although in some instances they are also applied on reduction of outstanding bonded indebtedness incurred to provide this type of service.

STATISTICAL SUMMARY OF GRIT CHAMBER USAGE AS RELATED TO TYPE OF SEWER SYSTEM

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This study of sewage treatment plants having grit chambers is one of a group of statistical summaries of water and sewage practice prepared by the Public Health Service (1) (2) (3). The basic data are from the "Inventory of Water and Sewage Facilities in the United States," which is maintained by the Division of Water Pollution Control in cooperation with the various state health departments. Grateful acknowledgment is due the engineering personnel of these state organizations who have effectively collaborated in the compilation of this basic information.

Data Included

During the preparation of the 1945 general sewage works summary (1), it was noted that many plants having grit chambers were served by sewer systems of the separate type. The extent of this practice and its implications on sewage works design guided the compilation of these data.

Summary information presented in this paper is based on the 1948 edition of the Inventory. Data are presented to show the number of sewage treatment plants having grit chambers with special reference to the type of sewer system. Selected operating data from a group of 30 plants are also included.

Information concerning the number of plants with grit chambers and the population served is presented in Tables I and II. Table I is arranged by states; Table II, by population groups based on the 1940 census population of the community in which the plant is located. Each table is subdivided by the type of sewer systems reported for the community in which the plant is located.

The quantity of grit removed from sewage in 30 American sewage treatment works is shown in Table III. These data are mainly from operating reports as abstracted in This Journal. Annual operating results over the period of years noted for each plant have been averaged to show the quantity of grit removed in cubic feet per million gallons of sewage. Data for years later than 1939 have been used.

Discussion

In 1948 there were 796 plants, serving more than 30,300,000 persons, having grit chambers as an integral unit of the treatment process. Of these, 522 plants, or 65.6 per cent, were served by separate sewer systems. Of the remainder, 173 plants were served by combined sewers, and 101 by both types. With respect to population, the major portion served by grit removal facilities was connected to combined sewers or to systems embodying both types; 41.1 per cent and 34.0 per cent of the total, respectively. These percentage data, particularly those for population, are greatly influenced by the practice in plants serving communities of over 100,000 population. If this group (over 100,000) is eliminated from consideration, almost half (48.9 per cent) of the population served by grit removal is connected to separate sewer systems.

Grit removal facilities are most com-

TABLE I.—Number of Plants Having Grit Removal and Estimated Population Served with Respect to Type of Sewer System, by States

State	Separate Sewers		Combined Sewers		Both Separate and Combined Sewers		Proportion of Total Having Grit Removal	
	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	Plants (%)	Pop. (%)
Alabama	7	152,700	—	—	—	—	6.0	29.8
Arizona	2	123,000	—	—	—	—	4.0	47.1
Arkansas	4	13,600	1	7,000	—	—	4.8	7.5
California	11	624,885	2	215,000	—	—	5.3	23.4
Colorado	4	405,250	—	—	—	—	7.5	66.6
Connecticut	13	152,400	5	412,000	5	132,400	46.0	79.9
District of Columbia	—	—	—	—	1	982,000	100.0	100.0
Florida	6	35,650	—	—	1	35,000	3.4	14.1
Georgia	26	75,170	3	309,000	—	—	18.2	73.4
Idaho	2	8,500	—	—	—	—	5.7	13.6
Illinois	26	121,170	56	3,314,240	2	5,900	29.2	65.9
Indiana	10	59,000	25	943,400	—	—	36.1	78.6
Iowa	37	290,210	8	196,000	1	8,000	14.9	62.4
Kansas	5	203,000	—	—	2	72,300	4.0	43.2
Kentucky	13	87,290	1	2,500	1	2,000	15.5	40.1
Louisiana	3	31,300	—	—	—	—	5.8	15.9
Maryland	5	948,450	—	—	—	—	9.3	90.7
Massachusetts	6	67,400	3	155,590	3	659,600	21.4	39.6
Michigan	12	124,845	12	2,464,990	13	596,950	30.3	85.7
Minnesota	4	30,700	4	913,015	—	—	3.8	73.7
Missouri	13	136,095	—	—	3	26,440	8.2	42.7
Montana	1	1,500	—	—	—	—	1.8	2.1
Nebraska	1	18,500	—	—	—	—	0.8	6.8
Nevada	1	2,500	1	20,000	—	—	8.3	28.9
New Hampshire	3	18,800	—	—	—	—	18.8	74.2
New Jersey	32	806,525	2	71,200	2	1,060,000	17.1	68.9
New Mexico	1	17,000	—	—	—	—	2.1	7.7
New York	78	866,185	8	939,010	21	3,170,600	36.7	81.2
North Carolina	63	352,510	—	—	—	—	22.7	47.1
North Dakota	3	2,810	6	58,800	—	—	11.0	41.4
Ohio	11	257,800	9	901,500	23	2,244,760	19.3	88.6
Oklahoma	2	111,260	—	—	—	—	1.0	15.4
Oregon	4	33,500	3	28,500	—	—	7.8	39.4
Pennsylvania	12	237,550	9	244,950	5	360,335	13.3	47.8
Rhode Island	3	53,000	—	—	1	262,000	33.3	77.0
South Carolina	9	128,100	—	—	—	—	5.8	33.3
South Dakota	1	10,000	—	—	—	—	1.3	5.4
Texas	60	506,265	2	307,000	1	423,000	12.9	46.9
Vermont	—	—	1	8,100	—	—	14.3	87.1
Virginia	6	199,600	—	—	—	—	6.3	54.9
Washington	5	46,175	3	84,000	2	29,205	10.8	52.7
West Virginia	3	17,800	—	—	—	—	1.8	21.5
Wisconsin	12	169,610	9	892,860	14	276,250	15.3	77.7
Wyoming	2	11,100	—	—	—	—	9.1	25.2
Total	522	7,558,705	173	12,488,655	101	10,346,740	13.1	62.4

TABLE II.—Number of Plants Having Grit Removal and Estimated Population Served with Respect to Type of Sewer System, by Community Population Groups

Population Group	Separate Sewers		Combined Sewers		Both Separate and Combined Sewers		Proportion of Total Having Grit Removal	
	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	Plants (%)	Pop. (%)
Less than 500	8	4,145	1	350	—	—	1.6	2.7
500 to 1,000	42	29,455	3	1,500	—	—	4.0	4.6
1,000 to 5,000	226	514,390	36	90,150	17	51,060	9.4	13.8
5,000 to 10,000	93	519,960	40	247,090	16	108,420	23.4	27.0
10,000 to 25,000	93	1,246,655	28	382,710	21	306,550	34.8	41.0
25,000 to 50,000	24	720,915	27	962,250	15	500,300	38.8	58.6
50,000 to 100,000	17	973,535	13	895,940	8	636,310	60.3	69.4
More than 100,000	19	3,549,650	25	9,908,665	24	8,744,100	57.6	79.8
Total	522	7,558,705	173	12,488,655	101	10,346,740	13.1	62.4

TABLE III.—Quantity of Grit Removed from Sewage in Various American Treatment Plants

City	Type of Sewers	No. of Years Record	Quantity of Grit (cu. ft./m.g.)
Akron, Ohio	Combined	1	7.26
Aurora, Ill.	Combined	7	3.56
Battle Creek, Mich.	Separate	2	0.76
Buffalo, N. Y.	Combined	6	2.67
Cleveland, Ohio:			
Easterly	Both	4	4.06
Westerly	Both	4	3.40
Southerly	Both	4	1.57
Cortland, N. Y.	Separate	1	0.76
Dallas, Tex.	Both	2	5.3
Washington, D. C.	Both	4	1.46
Elgin, Ill.	Combined	1	0.5
Elizabeth, N. J.	Separate	2	4.06
Findlay, Ohio	Both	2	1.5
Galesburg, Ill.	Combined	2	4.82
Gary, Ind.	Combined	4	8.37
Green Bay, Wis.	Combined	2	6.4
Hartford, Conn.	Combined	4	2.20
Indianapolis, Ind.	Combined	3	1.36
Jackson, Mich.	Combined	5	0.68
Marshalltown, Iowa	Separate	1	2.6
Marion, Ind.	Combined	1	1.1
Minneapolis–St. Paul, Minn.	Combined	5	4.5
Muskegon Heights, Mich.	Separate	2	4.8
New Britain, Conn.	Both	1	1.2
Niagara Falls, N. Y.	Combined	1	2.99
Richmond, Ind.	Combined	1	1.6
San Francisco, Calif.	Combined	1	10.0
Springfield, Ill.	Combined	1	0.83
Toledo, Ohio	Combined	4	1.6
Worcester, Mass.	Both	4	2.81

TABLE IV.—Per Cent of Plants Having Grit Removal Units, by Geographical Areas

Geographical Area[1]	Proportion of Total Plants Having Grit Removal (%)
New England	27.2
Middle Atlantic	24.2
South Atlantic	10.9
East North Central	24.4
East South Central	6.0
West North Central	7.5
West South Central	8.7
Mountain	4.5
Pacific	7.0
Total	13.1

[1] States included in each area are those used by the U. S. Census Bureau (see footnotes, Table III, THIS JOURNAL, **22**, 11, 1430; Nov., 1950).

mon in those plants serving the larger communities. Almost 80 per cent of the population connected to sewage treatment in communities of over 100,000 population is served by grit removal processes in 57.6 per cent of the total plants serving this group. Comparative percentage data for all groups (Table II) indicate readily the increase in per cent of plants with grit removal as the community size increases.

Of particular interest and significance is the number of plants in the smaller population groups having grit removal units. By far the major portion of these are served by separate sewer systems. This appears to indicate a departure from what has been considered more or less normal practice in the past: that grit chambers are not required with separate sewer systems except in unusual circumstances. Van Kleeck (4) recently noted that sentiment today is overwhelmingly in favor of the use of grit chambers in plants served by separate sewers. The data presented herein tend to substantiate this statement.

There are interesting divisions in practice of using grit chambers along state lines. In only five states are no grit removal units reported to be in use. In five other states less than 2 per cent of the total treatment plants have grit chambers. Connecticut, with 49.0 per cent of its plants equipped with grit removal units, has the highest percentage. It is followed by New York, where almost 37 per cent of the treatment plants are so equipped.

Percentage data for geographical areas are shown in Table IV. The practice of using grit removal units is predominent in the three areas comprising the northeastern part of the United States. The New England states, where 27.2 per cent of the treatment plants incorporate grit removal facilities, have the highest percentage, closely followed by the East North Central and Middle Atlantic groups with 24.4 and 24.2 percent, respectively. The Mountain group has the lowest percentage, 4.5, of plants so equipped.

Comparative data for 1945 and 1948 are given in Table V. Although there were significant increases in numbers of plants and population served by grit removal, total practice changed but slightly. In fact, a very slight decrease in per cent of plants having grit re-

TABLE V.—Number of Plants Having Grit Removal and Estimated Population Served in 1945 and 1948

Year	Number of Plants	Est. Pop. Served	Proportion of Total Having Grit Removal		Per cent Change[1]	
			Plants (%)	Pop. (%)	Plants	Pop.
1945	765	27,792,786	13.2	59.3	4.1	9.4
1948	796	30,394,100	13.1	62.4		

[1] Per cent change with respect to earlier year.

moval occurred. The per cent of population so served increased from 59.3 in 1945 to 62.4 in 1948; a gain of about 3 per cent.

The data in Table III represent readily available information concerning quantities of grit removal from sewage in American treatment works. No attempt has been made to correlate these data with the size of community, type of sewers, condition of sewers, or type of grit removal devices. The data were deemed too few for such treatment. However, from the few data available, it appears that unit quantities of grit from separate sewers may be as large as those recovered from combined systems. Certainly, the data are so variable as to require more detailed study as additional information becomes available.

Summary

Data from the 1948 "Inventory of Water and Sewage Facilities in the United States" are summarized to show the use of grit removal units in sewage treatment plants with respect to type of sewer systems serving the plant. Of the 796 plants serving more than 30,000,000 persons which had grit chambers, 522 or 65.7 per cent, were connected to separate sewer systems. The major portion of the population is served by plants connected to combined sewers or systems incorporating both types. Grit removal units are most common in plants serving the larger communities and in the states in the northeastern quarter of the United States. There is a considerable difference in practice along state lines. Of important significance is the number of plants in small communities having grit chambers. The majority of these plants is served by separate sewers. Data showing unit quantities of grit removed from sewage at 30 American treatment works are included.

References

1. Thoman, J. R., "Statistical Summary of Sewage Works in the United States." *Pub. Health Rep.*, Supplement 213 (Apr., 1950); abs., THIS JOURNAL, **22**, 7, 887 (July, 1950).
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GROUND GARBAGE STUDIES AT DETROIT

By Clyde L. Palmer and Isadore Nusbaum

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Detroit, Mich., approves and encourages the use of garbage grinders for the disposal of food wastes through its sewer and sewage treatment system. The use of garbage grinders unquestionably results in improved environmental sanitation and convenience and rightly deserves the popular acceptance that it presently enjoys. A wider use of garbage grinders appears inevitable. Nevertheless, although there are some data available in the literature pertaining to the effects of the introduction of ground garbage into sewage, there are still some rather wide variations in the reported results.

It has been quite definitely established that the introduction of ground garbage into a sewer and sewage treatment system will present no unusual operating problems; however, the amount and characteristics of the increased load have not been fully determined. Little has been added to the literature since the data published by Cohn (1) in 1934 and Carpenter *et al.* (2) in 1936. Calvert and Tolman (3) in 1936 presented the results of the effect on the Indianapolis sewage treatment plant of grinding the entire garbage produced in the city into the influent at the plant using a large commercial grinder.

The experimental data presented herein, although obtained in a laboratory-sized experiment, were designed to produce information which would indicate the ability of the existing sewage treatment facilities in Detroit to handle the load from the rapidly increasing number of home and commercial garbage grinders in the area contributing to the municipal sewer system and to indicate what extensions of facilities, if any, would be required.

To date, little or no effect of ground garbage on the character of the Detroit plant influent has been observed. It is estimated that at present the domestic grinder equivalent of home and commercial grinders tributary to the Detroit plant is about 15,000 units.

The experimental work, the results of which are reported herein, was designed to provide data on the following:

1. The proportion of garbage that goes into solution or colloidal suspension in the grinding process.
2. The chlorine demand of the liquid portion of ground garbage.
3. The B.O.D. of the liquid portion of ground garbage.
4. The physical characteristics in relation to particle size.

Procedure

It was decided that to grind a variety of materials, among which would be included a garbage that could be considered typical of the average ground into the sewage daily, as well as a number of separate materials, such as would be ground in large amounts by produce commission houses, food canning and preparation plants, and large restaurants. Although it might be assumed that domestic garbage collected from an average household would serve to define the average, this material was soon discarded as unusable for the experiment. Domestic garbage from any one household in any day is rather limited in variety

and the experiment was to be conducted on essentially fresh material, as garbage ground in domestic units is stored a relatively short time. The experiment was conducted during June, July, and August, 1950, at which time it was possible to obtain the widest variety of materials and garbage containing a variety of substances. As examples of average garbage more or less typical of the mean ground into the sewers daily, it was possible to obtain garbage from a large cafeteria located in the city. The garbage obtained consisted of well-mixed plate scrapings and of the waste from the many substances prepared daily.

The fresh garbage obtained each day was immediately taken to the sewage treatment plant laboratory and prepared for grinding and analysis. The grinder used was a Waste-King Pulverator, which had been mounted on a cart for demonstration purposes and served admirably for the experimental setup. This grinder produces a fine grind that has been accepted as satisfactory by Detroit; it does not differ substantially from the several acceptable grinders. A 0.5-lb. representative sample of the green garbage was placed in the grinder and ground with 1 gal. of tap water in 30 sec. This is approximately the manner in which the grinder would perform in the home. In only one case (raw fish) was it difficult to complete the grinding in the time allotted with the amount of water added. In all other cases, although the grinder was flushed between determinations, practically no

TABLE I.—Experimental Results of Ground Garbage Studies

Material Ground	Dry Solids (%)	Nonsettleable Solids (%)[1]	Cl_2 Demand of Ground Garbage Less Settleable Solids (p.p.m.)	B.O.D. of Ground Garbage Less Settleable Solids (p.p.m.)
Restaurant garbage	44.08	17.1	6.0	—
Restaurant garbage	26.00	17.6	5.9	—
Restaurant garbage	24.36	16.4	5.0	—
Restaurant garbage	22.61	24.1	7.9	2,300
Restaurant garbage	25.96	35.1	5.1	3,500
Restaurant garbage	35.81	10.4	4.9	1,390
Restaurant garbage	26.08	22.5	5.1	2,793
Restaurant preparation garbage	18.62	33.8	8.9	1,950
Restaurant preparation garbage	17.24	43.3	8.9	2,525
Domestic garbage	15.78	30.8	8.2	—
Leaf lettuce	11.73	29.6	4.7	—
Summer squash	7.93	43.9	4.2	—
Potato peelings	16.75	13.9	6.4	—
Potato peelings	16.42	13.4	3.5	994
Fresh string beans	7.56	47.0	13.8	—
Canned string beans	6.48	53.5	15.4	—
Fresh carrots	14.22	51.6	4.0	—
Fresh carrots	12.93	56.5	2.8	2,527
Diced canned carrots	8.28	74.1	5.0	—
Diced canned carrots	7.92	71.0	3.4	1,725
Raw fish	28.32	20.1	20.4	—
Celery tops	9.43	37.8	4.9	980
Carrot tops	15.07	31.8	6.8	1,250
Watermelon rind	4.75	64.0	1.7	1,210
Spinach stems	7.72	41.0	4.0	836
Juiced oranges	23.90	45.5	34.0	4,767
Rendered beef scraps	93.28	6.6	11.4	2,973
Head lettuce, outer leaves	4.80	41.9	3.5	578

[1] Based on dry solids.

TABLE II.—Chlorine Demand of Settled and Unsettled Ground Garbage Mixtures

Material Ground	Dry Solids (%)	Cl_2 Demand of Unsettled Ground Garbage (p.p.m.)	Cl_2 Demand of Ground Garbage Less Settleable Solids (p.p.m.)
Restaurant garbage	44.08	—	6.0
Restaurant garbage	26.00	—	5.9
Restaurant garbage	24.36	—	5.0
Restaurant garbage	22.61	13.1	7.9
Restaurant garbage	25.96	—	5.1
Restaurant garbage	35.81	9.8	4.9
Restaurant garbage	26.08	—	5.1
Restaurant preparation garbage	18.62	8.9	8.9
Restaurant preparation garbage	17.24	8.9	8.9
Domestic garbage	15.78	—	8.2
Rest. prep. garbage and plate scrapings	16.99	13.4	11.9
Rest. prep. garbage and plate scrapings	17.35	11.4	9.7
Rest. prep. garbage and plate scrapings	23.40	13.2	9.4
Rest. prep. garbage and plate scrapings	19.72	15.2	10.6
Average	23.86	12.9	7.5

significant material remained in the grinder after each grinding. Dry solids in the green garbage were determined on a sample of the original. The volume of the ground mixture in all cases was taken as 4 l. to simplify measurements and calculations. A number of volume measurements indicated that the volume error introduced was in the neighborhood of ± 1 per cent, which is not significant. Samples were permitted to settle for 30 to 60 min. It was assumed that the supernatant would then correspond to the material which would constitute the principal contribution of ground garbage to primary plant effluent. The ground garbage mixtures separated rapidly.

The supernatant obtained from the settled ground garbage mixture was analyzed for total solids, volatile solids, chlorine demand, and B.O.D. Some chlorine demand determinations were made on samples containing all the solids.

In addition, samples of ground garbage, ground garbage seeded with 1 per cent sewage, and raw sewage containing 1 per cent ground garbage mixture were agitated for 24 hr. with a multiple stirrer, of the type used for flocculation tests, at a peripheral speed in excess of 1 ft. per sec. The chlorine demands were then determined. The results of these various tests are given in Tables I and II.

Discussion

As noted in Table I, the nonsettleable solids, consisting of the suspended colloidal and dissolved solids remaining in the supernatant from the ground garbage mixes following settling, varied from 10.4 to 43.3 per cent on a dry basis, with an average value of 25.1 per cent. This value became as high as 74.1 per cent for a sample containing only diced canned carrots and as low as 6.6 per cent for rendered beef scraps.

These data have additional significance in that it was decided, if possible, to find some logical basis for a specification on the fineness of grind for domestic grinders. A recent publication recommended, in a proposed specification for home garbage grinders, that not over 5 per cent on a dry basis of the garbage ground shall pass a No. 40 U. S. sieve screen. It is quite evident from the data that this would be an impossible figure to reach and yet produce a grinder that would perform as required.

Practically no valid data are avail-

able on the increase in chlorine demand to be expected as a result of the disposal of large amounts of ground garbage into a sewer system. The literature was searched for data on chlorine demands of ground garbage mixtures, the only positive reference found being that of Rudolfs (4), in which the estimate is made that if 100 per cent of the garbage in an area is ground into the sewage, the chlorine demand in the effluent from the settled mixture would be increased by 20 to 50 per cent. This is not borne out by data obtained during the course of this experiment. The chlorine demand of the supernatant from ground mixed garbage mixtures varied from 4.9 to 11.9 p.p.m., with an average of 7.5 p.p.m. (Table II). The chlorine demand of the unsettled garbage mixtures varied from 8.9 to 13.4 p.p.m., somewhat higher than the settled material, but of not much greater significance. Because it might be conservatively estimated that the dilution afforded in the sewers is 100 to 1, the increase in chlorine demand of the effluent from primary sedimentation may vary from 0.05 to 0.12 p.p.m. In a sewage with normal chlorine demands of 3 to 9 p.p.m., the increase in the chlorine demands based on these data would vary from 0.56 to 4.0 per cent.

It might be thought that putrefactive changes in the ground garbage while in transit through the sewers would cause the production of compounds with a high chlorine demand. In a well-designed and well-ventilated sewer system, it is more likely that there will be a constant oxidation of the readily oxidized substances and a reduction in the chlorine demand. As previously noted under "Procedure," an attempt was made to determine the effect of ground garbage on chlorine demands by mixing a 1 per cent ground garbage in sewage combination in such a manner as to duplicate normal sewage velocity and ventilation conditions. In every case there was a decrease in the chlorine demand after mixing. There was no significant difference between the chlorine demands of the sewage or sewage-garbage mixture after agitating.

Undiluted ground garbage mixture and ground garbage seeded with 1 per cent sewage when mixed as above showed an increase in chlorine demand after agitation; however, the increase was not enough to greatly influence the chlorine demand of sewage to which ground garbage had been added in amounts approaching addition of 100 per cent garbage solids in an area.

Some doubt may exist as to the effectiveness of the residual chlorine resulting from the chlorination of ground garbage mixtures, as it is generally considered that protein and degenerated protein substance chloramines have little germicidal effect on bacteria. A limited number of ground garbage samples were seeded with raw sewage to produce an M.P.N. of 4,000,000 to 5,000,000 per 100 ml. A portion of the seeded sample was then chlorinated to produce a residual of 0.5 to 1.0 p.p.m. The reduction after a 15-min. contact time was greater than 99 per cent.

In 1949, the Detroit Department of Public Works collected an average of 713 tons per day of garbage with a variation of 30 per cent from the mean in the maximum and minimum collected. The corrected dry grindable garbage collected would be about 140 tons per day. This would place the addition of green garbage to Detroit sewage in the neighborhood of two tons per m.g. Calvert and Tolman (3) stated that the addition of two tons per m.g. seemed to aid the sedimentation of sewage solids and increased the B.O.D. of settled sewage only a nominal amount.

Based on the solids data presented herein, the dry solids to be handled at the Detroit sewage treatment plant, if 100 per cent of the garbage produced were ground into the sewage, will be increased from a minimum of 35 per

cent to a maximum of 65 per cent, with an average of 50 per cent.

Ignition of the dried nonsettleable solids residue showed the highly organic nature of the material, with more than 90 per cent of the dry solids being volatilized. This is reflected in the B.O.D.'s of the settled mixture, which varied from 1,390 to 3,500 p.p.m. for mixed garbages.

Although at present the B.O.D. of the Detroit effluent is not a major factor, because the average flow in the Detroit River is 180,000 cu. ft. per sec. of water saturated or supersaturated with oxygen, the B.O.D. contribution of the garbage was determined. The average increase in the B.O.D. of sewage containing 100 per cent of the garbage would be from 20 to 25 per cent, based on the data previously mentioned.

The data obtained in this experiment agree substantially with those obtained by Calvert and Tolman (3) at Indianapolis by grinding the entire garbage production of the city into the influent sewage at the plant using a large commercial grinder with properly spaced bar openings. Experience at Detroit has shown that large commercial garbage grinders installed in restaurants, food produce establishments, super markets, etc., will produce a ground garbage almost identical in character to that produced by the home grinder.

Conclusions

The following conclusions were reached, on the basis of the data reported herewith, concerning the results of garbage grinding and the effects of the introduction of ground garbage into a sewer system:

1. On the average, 25 per cent of the dry solids of garbage will go into solution or nonsettleable suspension in the grinding process.
2. Limitations on acceptable garbage grinder operation should specify that not more than 30 per cent, on the dry basis, pass a No. 40 U. S. Standard sieve.

If it is assumed that 100 per cent of a community's garbage is ground and introduced into the sewer system for disposal at the sewage treatment plant, further conclusions may be reached, as follows:

3. The chlorine demand of the effluent from the primary sedimentation process may be increased 0.12 p.p.m., or about 4 per cent, as a maximum.
4. The average increase in B.O.D. of primary effluent would be from 20 to 25 per cent.
5. The increase in solids to be handled at a primary plant, such as the Detroit plant, would average about 50 per cent.

Acknowledgments

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SALMONELLA IN IRRIGATION WATER

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Tanner (1) and more recently Rudolfs, Falk, and Ragotzkie (2) have reviewed the literature on the occurrence and survival of pathogenic and nonpathogenic enteric bacteria in soil, water, sewage, and sludges, and on vegetation irrigated or fertilized with these materials. It would appear from these reviews that fruits and vegetables growing in infected soil can become contaminated with pathogenic bacteria, and that these bacteria may survive for periods of a few days to several weeks or more in the soil and on vegetation. Few field studies have been made, however, on actual irrigation water and on growing crops which have been irrigated with diluted raw sewage or primary treated sewage effluents. Gaub (3) reported one instance of the isolation of *Shigella paradysenteriae* (Flexner) from cabbage that entered the Denver market from farms north of the city. The farms were irrigated with sewage-contaminated water. Apparently, however, the samples had been subjected to the usual handling associated with harvesting and marketing, and, therefore, the source of contamination is not clear.

Falk (4) and Rudolfs, Falk, and Ragotzkie (5) studied the relative incidence of coliform organisms on tomatoes grown on three plots of ground: one plot irrigated with settled sewage concurrently with growth, one irrigated previous to planting but not further, and one with no previous or concurrent irrigation. Except for the tomatoes with abnormal stem ends, there was no material difference in coliform counts per gram of tomatoes from the three plots. These same authors further found that *Salmonella cerro* and *Shigella alkalescens* organisms sprayed on growing tomatoes disappeared within two to seven days, whereas organisms of the coliform group remained for considerably longer periods. They concluded that "if sewage irrigation or night soil application is stopped one month before harvest, the fruit, if eaten raw, would not be likely vectors for the transmission of human bacterial enteric diseases." In the Western States, however, it is common practice to irrigate several times weekly right up to the day of harvest.

Wright (6) has emphasized the importance of irrigation for the economic and agricultural development of the Western States and has pointed to the need for uniform requirements for irrigation water based on factual evidence. The study reported herein was undertaken to assess further the public health hazard in using sewage-contaminated water for the irrigation of truck crops, which may be consumed raw. Attempts are being made to develop quantitative procedures for the estimation of enteric pathogens in irrigation water and on the crops irrigated with this water. The present paper is a preliminary report on the isolation of *Salmonella* organisms from sewage-contaminated irrigation water.

Methods and Results

Early attempts with direct plating and many combinations of enrichment broths and selective media yielded only paracolon organisms after coliforms,

TABLE I.—Incidence of *Salmonella* in Irrigation Water, 1950

Source	Quantity Examined (ml.)	No. of Samples	No. of Samples Positive for *Salmonella*	Positive Samples When Denver Effluent Was	
				Chlorinated	Not Chlorinated
Burlington ditch[1]	1	9	3	—	3
Gardener mutual ditch[1]	1	10	1	1	—
Wannemaker ditch[2]	1	2	0	—	—
Burlington ditch	10	1	0	—	—
Gardener mutual ditch	10	11	5	1	4
Burlington ditch	100	1	0	—	—
Gardener mutual ditch	100	59	14	8	6
Wannemaker ditch	100	6	0	—	—
Burlington ditch	1,000	5	0	—	—
Gardener mutual ditch	1,000	9	0	—	—
Total	—	113	23	10	13

[1] South Platte water below Denver sewage treatment plant.
[2] Clear Creek water below Golden sewer outfall.

proteus, and alcaligenes had been eliminated or discarded. Studies on the growth lags of these organisms, as well as those of *Salmonella* and *Shigella* in enrichment media, as suggested by the work of Kauffmann (7), indicated that the nonpathogens were inhibited only in the early hours of incubation. Accordingly, experiments were set up to test the recovery of *Salmonella* and *Shigella* mixed with irrigation water and inoculated into several types of enrichment broth with transfer to selective plating media after incubation for 6, 9, 12, and 24 hr. at 37° C.

The most productive combination, at least for *Salmonella*, was tetrathionate broth (Difco) incubated at 37° C. for 6 to 9 hr.* followed by streaking a large loopful of the enrichment growth on bismuth sulfite agar plates. The plates were incubated for 36 to 40 hr. This method was then tried on the irrigation water alone without added pathogens. Black colonies on bismuth sulfite agar, particularly those with metallic sheen and surrounding black or brownish zone, were picked to SS agar plates for purification, from which, after 24-hr. incubation at 37° C., representative colonies of the colorless types were inoculated into Kligler's iron agar. Final identification included the usual biochemical tests for *Salmonella* and agglutination with polyvalent and group antisera. All positive cultures were confirmed and identified as *Salmonella* by the Communicable Disease Center at Chamblee, Ga.

Table I shows the distribution of positive samples among all the samples tested with this combination of tetrathionate broth and bismuth sulfite plates. The 1-ml. quantities were inoculated into 10 ml. of single-strength tetrathionate broth; 10-ml. quantities were divided into five portions of 2 ml. each in 20 ml. of single-strength tetrathionate; 100-ml. inocula were filtered through Seitz pads (ST–1) with 20-lb. pressure, the pads quartered with sterile scissors, and each quadrant placed in 20 ml. of single-strength tetrathionate, shaken, and incubated. A few experiments with 1-l. inocula were made by centrifuging in a Foerst continuous centrifuge, the sediment being divided among four tubes of 20 ml. each single-strength tetrathionate.

* A few very recent experiments, however, have given better results after 18 to 24 hr. incubation. The reason for this difference is not yet apparent.

It may be noted from Table I that four out of 21, or 19 per cent, of the 1-ml. samples were positive for *Salmonella* organisms. Of these four positives, three were obtained at a time when the effluent from Denver's primary treatment sewage disposal plant was not being chlorinated, due to technical difficulties. Of the 12 10-ml. samples, 5, or 42 per cent, were positive for *Salmonella*. Again, four of the five positive samples were obtained when chlorination of the sewage plant effluent was interrupted.

Of the 66 100-ml. samples, 14, or 21 per cent, were positive for *Salmonella*. In these experiments chlorination of the effluent apparently made no difference, eight samples being positive when chlorination was used, and six when it was not. No positives were obtained from the 14 1-l. samples.

It must be emphasized that these experiments were carried out over a period of eight months from March to November, 1950, and that the various quantities of inocula cannot be compared, as they were not obtained at the same time. Further, the dilution of the effluents by the river or creek before the water entered the irrigation ditches varied considerably during the course of these experiments; marked changes in the proportions of interfering organisms, such as proteus, were noted. Nevertheless, it seems significant that 20 per cent, or 23 out of the 113 samples, were shown to contain *Salmonella*.

TABLE II.—Species of *Salmonella* Isolated from Irrigation Water and the Number of Different Samples from Which They Were Isolated, 1950

Species	Number of Times Isolated
S. anatum	3
S. bareilly	1
S. cubana	1
S. derby	1
S. montevideo	5
S. newington	2
S. newport	3
S. oranienburg	1
S. paratyphi B	2
S. senftenberg	3
S. tennessee	1
S. typhi	1
S. typhi murium	3

TABLE III.—Coliform Index of Irrigation Water Samples, 1950 (Confirmed M.P.N. Counts per 100 ml.)

		Denver Effluent	
		Chlorinated	Not Chlorinated
No. of samples		5	6
Salmonella positive	Median	230,000	42,000,000
	Low	130,000	460,000
	High	620,000	>230,000,000
No. of samples		28	15
Salmonella negative	Median	62,000	23,000,000
	Low	600	600,000
	High	620,000	>2,300,000,000

Table II shows the species of *Salmonella* isolated and the number of different samples from which they were isolated. *S. montevideo* was isolated from five samples. *S. anatum*, *S. newport*, *S. senftenberg*, and *S. typhi murium* were each isolated from three samples. *S. newington* and *S. paratyphi B* were each isolated twice; *S. bareilly*, *S. cubana*, *S. derby*, *S. oranienburg*, *S. tennessee*, and *S. typhi* were each isolated only once.

Attempts were made to isolate *Salmonella* from the washings of vegetables irrigated with water from the Gardener ditch. Plants were removed from the ground by placing a sterile paper bag over the entire plant and either twisting it from the roots or pulling the whole plant up without touching it directly with the hands. With sterile forceps and knife, 200 g. of the edible portion of each sample were removed to a sterile jar and washed with 2,000 ml. of sterile tap water containing 0.1 per cent Triton X100. Inocula ranging from 1 to 1,000 ml. of these washings were then tested in the same manner as the water samples previously described. Of 45 samples of celery, lettuce, and cabbage, not a single sample was positive for *Salmonella* organisms. Both the Triton in this concentration and the vege-

table juices were shown to have no effect on *Salmonella typhi*.

Coliform and enterococcus counts were run on most of the samples of water and vegetables. Multiple-tube dilution techniques were followed, lauryl sulfate tryptose broth being used for the presumptive coliforms, followed by confirmation in brilliant-green bile broth. Dextrose-azide broth (Difco) with incubation at 37° C. for 24 to 48 hr. was used for the presumptive enterococcus counts, with transfer to SF broth of Hajna and Perry (8) incubated at 45° C. for 24 to 48 hours for confirmation. Table III gives a summary of the coliform data on the irrigation water samples. A comparison of the median values of the samples shown to be positive for *Salmonella* with those which were negative suggests that a higher coliform index is associated with the presence of *Salmonella*. The data on enterococci were not conclusive, due to poor confirmation of the presumptive positives. B.O.D. values on the samples of irrigation water showed no correlation with the *Salmonella* positives.

Discussion

When 100-ml. quantities of irrigation water were filtered through Seitz pads, it was noted that not more than one quadrant of any one pad was positive for *Salmonella*. Further, the practice of taking several samples intermittently (at about 5-min. intervals) was more productive than taking a single large spot sample and dividing it. These observations suggest that the contamination in the water is not only intermittent, but that the pathogens are probably in particles of organic matter. It also seems probable that these particles contained more than one organism, as in the recovery experiments, using irrigation water and adding known pathogens, approximately 100 organisms per ml. of inocula were required to get positive recoveries. It is recognized, however, that adding pure suspensions of organisms is not the same as having the organisms in their natural state protected by enveloping organic material.

It is surprising that with definite contamination of the irrigation water, no *Salmonella* were recovered from the vegetables irrigated with this water. This was true even during a three-week period when the Gardener ditch water consisted of 60 per cent raw sewage, due to by-passing of the Denver sewage while additional aerators and clarifiers were being cut in at the sewage treatment plant. It is possible, of course, that the methods of isolation were more satisfactory for water than for vegetable washings. This point is being explored further. However, the common method of irrigating in this area is simply to allow the water to flow in the furrows between the rows of plants, and not to flood the field. Therefore, any organisms in the water would probably have to be splashed onto the leaves and stems above the ground or conveyed to the plant by some other means. Root crops, on the other hand, might be expected to be contaminated to a greater extent.

Summary and Conclusions

Salmonella organisms were recovered from a significant proportion of samples of irrigation water contaminated with a primary-treated sewage plant effluent. These same organisms, however, were not recovered from samples of vegetables irrigated with this water. Further work involving more samples and improvement of methods is now underway.

Acknowledgment

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HOSPITAL RADIOACTIVE WASTES NOT DANGEROUS

The problems of radioactive waste disposal from hospitals using these materials in research work have been under study by the U. S. Atomic Energy Commission. Hazards to plumbing and sewage disposal workers from wastes of this type, although potentially great, are minimized by the procedures set up by the Commission as precautionary measures to be taken by the users.

Concerning this study, the "Tenth Semiannual Report of the Atomic Energy Commission" (July, 1951) says:

"In the interests of public health and of convenience to users of isotopes, an AEC-supported project at Mount Sinai Hospital in New York is investigating the possible hazards of releasing radioisotope wastes into public sewers. Evidence indicates that hospitals disposing of radioactive iodine and phosphorus—the isotopes chiefly used in their research—cause no danger to sewage disposal workers because the volume and rate of flow under normal circumstances dilutes the active material to a safe level.

"Plumbing fixtures through which isotope wastes had passed were dismantled, tested, and found below any degree of radioactive contamination that might be hazardous to plumbers working on the fixtures."

MATERIALS CHIEF COST IN BUILDING NEW SEWAGE WORKS

Materials costs represent approximately two-fifths and labor a little over 30 per cent of the cost of building new systems, according to figures (Table I) from a survey conducted jointly by the U. S. Labor Department's Bureau of Labor Statistics and the Federal Security Agency's Public Health Service. Engineers' reports on a sample of 200 projects built in 1948, 1949, and 1950 provide the basis for a distribution of expenditures per million construction dollars for the labor, materials, and supplies needed to build these projects, and for overhead, profit, and equipment charges.

The data of the survey were secured from a sample of representative sewage systems constructed in 1948, 1949, and 1950, as selected by Public Health Service engineers. Although the sampling methods limit the reliability of the survey results, it is believed that the data will be valuable to analysts concerned with this type of construction. The promulgating agencies note that the only other data of this kind known to be available relate to 1940 and cover Public Works Administration projects analyzed by the Bureau of Labor Statistics.

TABLE I.—Expenditures per $1,000,000 for Construction of New Sewage Works[1]

Items	Expenditures ($1,000)		
	Total[2]	Sewage Treatment Plant	Sewage Collection[3]
All items	$1,000	$1,000	$1,000
Labor	317	280	335
Overhead, profit, and equipment charges	241	173	273
Supplies	17	12	20
Explosives	1	[4]	1
Fuel	8	7	9
All other, incl. small tools	8	5	10
Materials	425	535	372
Metal products	121	165	100
Bolts, nuts, washers, rivets	1	1	1
Castings, iron and steel	10	1	14
Forgings, iron and steel	[4]	1	[4]
Hardware	[4]	1	[4]
Hydrants and valves	5	11	2
Lead	1	1	1
Metal doors, windows, frame, trim	2	4	[4]
Nails and spikes	1	1	[4]
Pipe and fittings	29	57	15
Cast iron	20	40	11
Wrought iron and steel	5	11	2
Copper and other nonferrous metals	3	6	2
Plumbing fixtures and supplies, excl. pipe	1	2	1
Sheet metal	1	4	[4]
Steel, reinforcing	43	50	40
Steel, structural	16	13	18
Tanks and towers	1	3	—
Wire and wireworks products	3	4	2
Metal products, n.e.c.[5]	8	10	6

TABLE I.—Expenditures per $1,000,000 for Construction of New Sewage Works[1]—Continued

Items	Expenditures ($1,000)		
	Total[2]	Sewage Treatment Plant	Sewage Collection[2]
Machinery and equipment	80	159	42
Electrical equip. (motors, generators, etc.)	8	17	3
Electrical wiring and fixtures	6	14	2
Elevators and elevator equipment	[4]	1	—
Heating and ventilating equipment	3	7	1
Pumps and pumping equip. (incl. prime movers)	14	23	10
Sewage waste treatment equipment	44	84	24
Water meters, regulators, gauges	4	8	2
Foundry and machine shop products, n.e.c.[5]	2	6	[4]
Stone, clay, glass products	170	166	172
Brick and hollow tile	9	12	8
Cement	17	10	20
Cement asbestos pipe	4	[4]	5
Clay pipe	21	6	29
Concrete pipe	23	6	32
Concrete, premixed	68	96	55
Marble, granite, slate	1	3	—
Sand, gravel, crushed stone	24	24	23
Stone, clay, glass products, n.e.c.[5]	3	8	1
Lumber products	26	25	27
Other materials	28	21	32
Expansion joints (hemp, jute, joint comp., etc.)	2	1	2
Paints and varnishes	1	4	[4]
Paving materials and mixtures	20	4	28
Roofing materials	[4]	[4]	[4]
Rubber products	1	2	[4]
Materials, n.e.c.[5]	4	10	1

[1] See text for source of data and limitations of survey.

[2] An expenditures distribution for all sewage disposal systems was derived by combining the separate sample data for treatment plants and collection works, using as weights the aggregate 1948 contract awards for these types of projects, rather than the proportions represented by the sample contract values.

[3] The sample analyzed included a few projects for which the treatment plants could not be segregated. Such projects are included in this category.

[4] Less than $500; sum combined with amount for the "not elsewhere classified" items.

[5] n.e.c. = not elsewhere classified.

Expenditures on sewage disposal systems for the presently critical metal products were offset to a large extent by costs allocated to cement, clay, and stone products. This reflects primarily the use of clay and concrete pipe on sewage lines, instead of metal pipe and fittings.

A substantial amount of sewage treatment plant construction expense was for machinery and equipment to operate the works, an item that is very minor in the case of the sewage collection lines. Other materials expenses were fairly similar for the two parts of the sewage disposal system.

Because of the deeper and more extensive excavation needed for installation of sewer pipes, charges for the use of construction machinery were a much more significant item of expense for construction of sewage collection lines than for any of the other parts of the sewage disposal systems.

Industrial Wastes

COLOR IN INDUSTRIAL WASTES

I. DETERMINATION BY SPECTROPHOTOMETRIC METHOD*

By Willem Rudolfs and William D. Hanlon

Industrial waste effluents containing color and discharged into streams are of considerable importance, particularly in connection with their effect on water treatment and visual observation by the layman. An industrial waste may have received a very high degree of treatment, as measured by reduction in the suspended solids and B.O.D. with little effect on the color. The observer, on seeing the color, is not readily convinced that the pollution has been abated. Moreover, such color frequently can be traced for a considerable distance in the stream.

To express the color of industrial waste solutions or evaluate the effectiveness of waste color reduction processes, it is necessary to specify the color characteristics in definite values related to the color sensations realized when viewing the wastes. The present standard method (5) for the color determination of water is not adequate, as actual hue and brightness characteristics cannot be effectively determined and expressed. Color determination results by the standard method also vary with the type of light source and the vision of the observer.

I.C.I. Standards

Color is actually the sensation realized by a person when light energy impinges on the retina of the eye (2) (6). The color sensation experienced when viewing a waste solution depends upon the source and rate of flow of incident light, the absorbing or reflecting characteristics of the colored medium, and the human vision. The correlations between these factors can be very complex and the standard specification of a color requires the use of standard light source and observer data. The appearance of a colored object can vary considerably when illuminated by light sources having different spectral energy characteristics. Furthermore, the appearance will vary with the observer, because of the variation in the sensitivity of the eye to the various spectrum regions.

Standards were adopted by the International Commission on Illumination (I.C.I.) (4) in 1931, including three standard illuminants (A, B, and C) and a standard observer. Standard illuminant C has a spectral energy distribution curve (Figure 1) similar to that of average daylight. Because average daylight is the predominating light source for industrial wastes, the data for illuminant C are of the most value for this type of work.

Tristimulus Values

The data for the standard observer were obtained from a group of individuals having normal color vision. A person can match the effect of any color stimulus by mixing light from three primary sources. The group of observers supplying these data determined the proportions of three pri-

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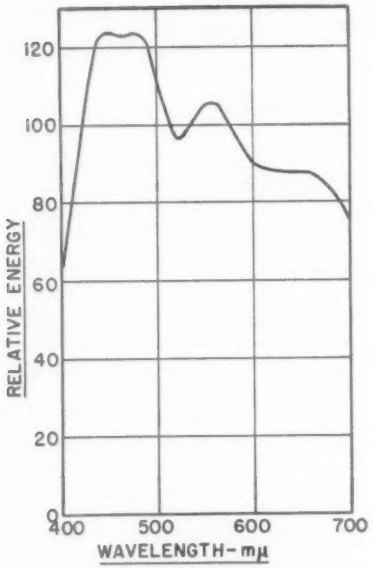

FIGURE 1.—Relative energy distribution curve for I.C.I. illuminant C.

maries (red, green, and violet) necessary to match a unit quantity of light at a single wavelength. These proportions of the primaries are known as tristimulus values at the selected wavelength. Tristimulus values were determined for points along the entire visible spectrum range from 400 to 700 millimicrons. The tristimulus curves for each of the primaries $\bar{x}$ (red), $\bar{y}$ (green), and $\bar{z}$ (violet) are shown in Figure 2.

When the I.C.I. adopted the tristimulus standards, the curve for the green primary $\bar{y}$ in Figure 2 was selected so that it would correspond with the visibility curve for a normal eye (Figure 3). This curve shows the relative brightness of equal amounts of spectral energy at various wavelengths in the visible region. Because the $\bar{y}$ primary is identical to the visibility curve, the primary data can be used directly to determine the relative brightness of light to the normal eye.

Solution Transmittance Data

To determine the color specification of a solution in terms of the I.C.I. standards it is necessary to have the transmittancy data for the solution over the visible spectral range. These data can be determined by using a spectrophotometer, which is an optical instrument used to disperse light into nearly monochromatic spectrum components. The narrow beam of monochromatic spectrum energy is passed through each of two absorption cells of uniform transmission thickness. In one cell, distilled water is used as the blank considered to transmit 100 per cent of the incident light. The second cell contains the colored solution and the amount of energy that will pass through this cell relative to the blank cell is known as the transmittancy of the solution for the selected wavelength. In other words, the transmittancy value is the percentage of incident light that will pass through the colored solution.

A series of transmittancy values can be determined for narrow spectral band widths along the entire visible spectrum range. These transmittancy values, when plotted against wavelength, provide a transmission curve for the colored solution. A typical transmission curve for an industrial yeast waste might appear like that in Figure 4. The transmittancy values for this waste increase toward the longer wavelength values, indicating that the hue of this color would probably be in the orange-red region.

Evaluation of Color Data

Weighted Ordinate Method

With the transmission curve, energy distribution data for illuminant C, and the standard tristimulus values for the I.C.I. primaries, it is possible to determine the proportional amount of each primary necessary to match the color of the sample. Basically, the weighted ordinate method (3) consists

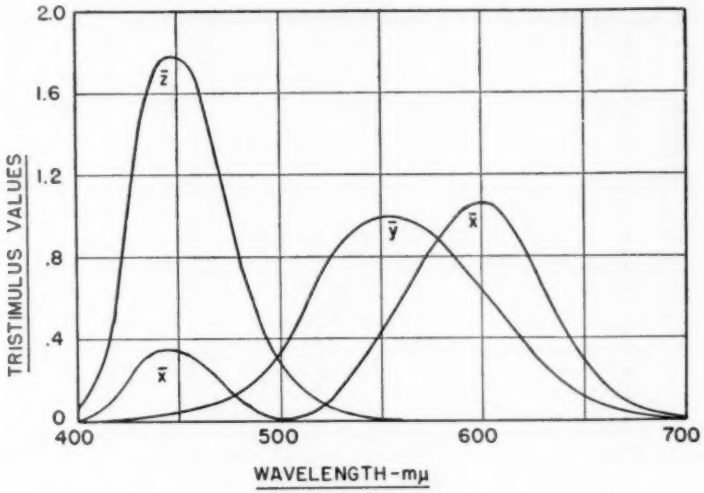

FIGURE 2.—Tristimulus values for the visible wavelength region.

of dividing the visible spectrum into a number of equal wavelength intervals and then determining the contribution of energy for each of the intervals to the total energy. The energy of illuminant C (Figure 1) for the selected interval is multiplied by the corresponding tristimulus value (Figure 2) for each of the primaries. This product is multiplied by the transmittancy value for the same interval.

This procedure is repeated for each of the intervals in the visual range and the resulting products are added

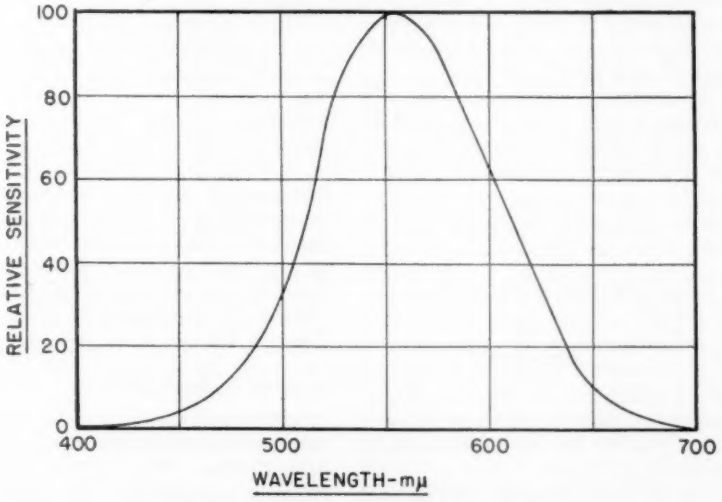

FIGURE 3.—Sensitivity curve for a normal eye.

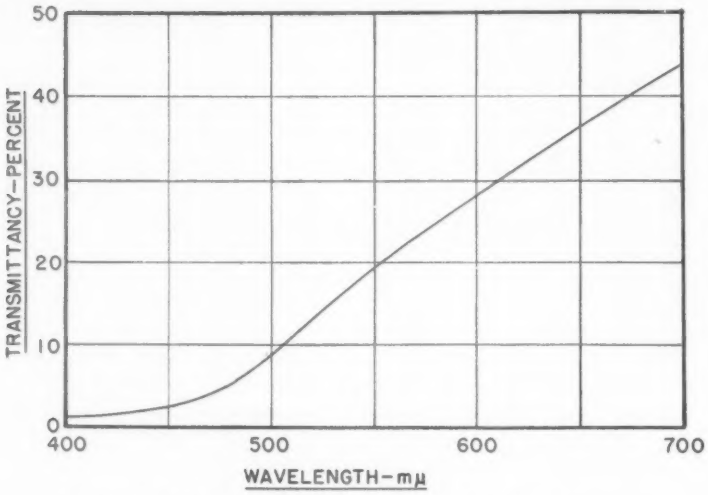

FIGURE 4.—Transmission curve for an industrial yeast waste.

for each of the primaries to give three tristimulus values for the color sample. These values are designated as X (red), Y (green), and Z (violet). The brightness of the color sample is determined by calculating the ratio of the Y value to the Y value of a hypothetical solution having a 100 per cent transmission at every wavelength in the visible range. This value is expressed as a percentage value.

Trichromatic Coefficients—The tristimulus values X, Y, and Z are used in the following relationships to give the trichromatic coefficients x, y, and z:

$$x = \frac{X}{X + Y + Z}$$

$$y = \frac{Y}{X + Y + Z}$$

$$z = \frac{Z}{X + Y + Z}$$

When multiplied by 100, the trichromatic coefficients x (red), y (green), and z (violet) are the percentages of the three primaries.

Chromaticity Diagram—The quality of a color is expressed in terms (1) which describe the sensations realized when light energy reaches the observer. The hue (red, yellow, green etc.) of the color is designated by the term "dominant wavelength," the degree of brightness by "luminance," and the saturation (pastel, pale, etc.) by "purity."

The trichromatic coefficients x and y form the coordinates of the chromaticity diagram shown in Figure 5. The elliptical border of this diagram represents the 100 per cent spectral colors, and the center, C, is the point of zero purity or illuminant C. The intermediate elliptical lines provide purity values between zero and 100 per cent. The dominant wavelength of any point on the diagram is indicated by its position relative to the wavelength lines radiating from point C to the 100 per cent purity line.

Selected Ordinate Method

The weighted ordinate method involves many calculations and a great deal of time. This difficulty can be reduced considerably by using the simplified selected ordinate method (3)

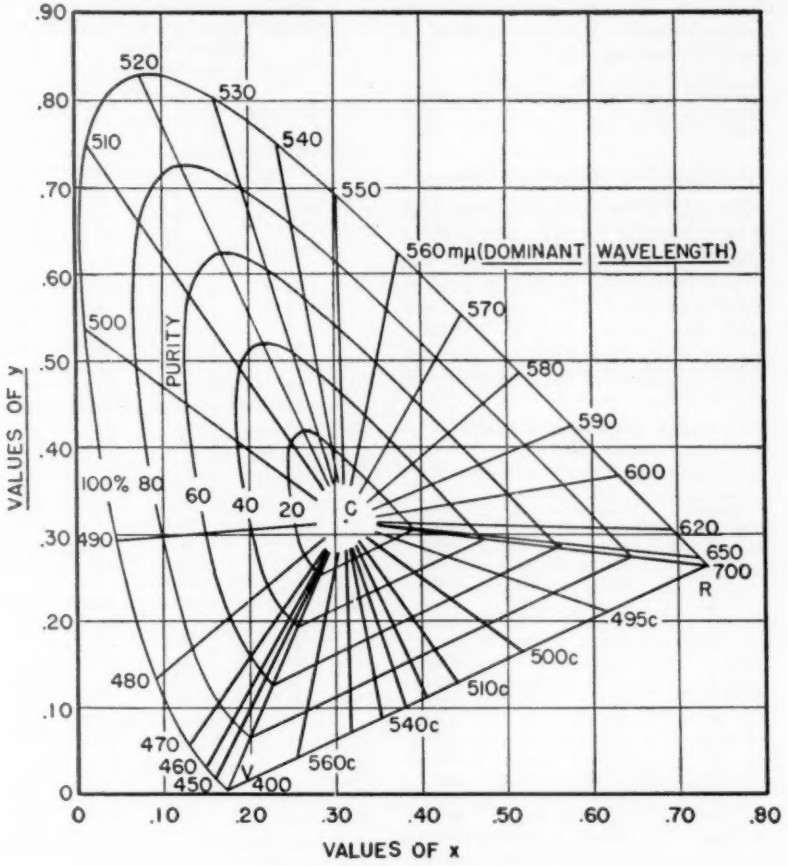

FIGURE 5.—Chromaticity diagram.

where the transmittancy values are read at the selected wavelengths shown in Table I.* The transmittancy values for each of the primaries are totaled and multiplied by the appropriate factor, provided in Table I, to give the tristimulus values X, Y, and Z. The trichromatic coefficients are then obtained as in the weighted ordinate method. The brightness of the sample by this method is taken directly as Y.

* For more detailed data, the 100 wavelength values in Hardy's "Handbook of Colorimetry" may be used (3).

Example—Figure 4 represents the transmission curve for a yeast waste. Transmittancy values selected from this curve for each of the primary selected ordinates provided in Table I are presented in Table II. The transmittancy totals for each primary were multiplied by the 30 ordinate factors in Table I to give the tristimulus values and trichromatic coefficients indicated. The brightness of this waste sample was taken directly as the tristimulus value Y and the trichromatic coefficients x and y were applied to the chromaticity diagram (Figure 5) to

obtain the dominant wavelength and purity values. The specification of this color was found to be:

Dominant wavelength (millimicrons)	582
Luminance (%)	20.2
Purity (%)	79

Procedure for Industrial Wastes

The color of an industrial waste shall be considered as the color of the waste solution after removal of the suspended material, including the pseudo-colloidal particles. The suspended material shall be removed by filtration through a standard filter aid medium. Color adsorption by calcined filter aids is practically negligible for the quantity of filter aid required, and this possible source of error shall be eliminated by filtering larger quantities of waste before taking a sample of the filtrate for color determination purposes. Centrifuging shall not be used, as the results will vary with the size and speed of the centrifuge. Furthermore, particles with a specific gravity lower than that of water will tend to float or remain in suspension.

The light transmission characteristics shall be determined at the pH value of the waste and at pH 7.6. The temperature of the waste for these

TABLE I.—Selected Ordinates for Illuminant C

Ordinate Number	X (mμ.)	Y (mμ.)	Z (mμ.)
1	424.4	465.9	414.1
2[1]	435.5[1]	489.5[1]	422.2[1]
3	443.9	500.4	426.3
4	452.1	508.7	429.4
5[1]	461.2[1]	515.2[1]	432.0[1]
6	474.0	520.6	434.3
7	531.2	525.4	436.5
8[1]	544.3[1]	529.8[1]	438.6[1]
9	552.4	533.9	440.6
10	558.7	537.7	442.5
11[1]	564.1[1]	541.4[1]	444.4[1]
12	568.9	544.9	446.3
13	573.2	548.4	448.2
14[1]	577.4[1]	551.8[1]	450.1[1]
15	581.3	555.1	452.1
16	585.0	558.5	454.0
17[1]	588.7[1]	561.9[1]	455.9[1]
18	592.4	565.3	457.9
19	596.0	568.9	459.9
20[1]	599.6[1]	572.5[1]	462.0[1]
21	603.3	576.4	464.1
22	607.0	580.4	466.3
23[1]	610.9[1]	584.8[1]	468.7[1]
24	615.0	589.6	471.4
25	619.4	594.8	474.3
26[1]	624.2[1]	600.3[1]	477.7[1]
27	629.8	607.7	481.8
28	636.6	616.1	487.2
29[1]	645.9[1]	627.3[1]	495.2[1]
30	663.0	647.4	511.2
Factors:			
30 ordinates	0.03269	0.03333	0.03938
10 ordinates	0.09806	0.1000	0.11814

[1] For relatively non-selective transmission curves, these values may be used.

TABLE II.—Trichromatic Data for an Industrial Yeast Waste by the Selected Ordinate Method

Ordinate Number	Transmittancy Values (%)		
	X	Y	Z
1	1.2	3.2	1.1
2	1.5	6.5	1.1
3	2.0	8.3	1.1
4	2.5	10.5	1.2
5	3.0	11.9	1.2
6	4.1	13.0	1.4
7	15.5	14.1	1.5
8	18.0	15.0	1.8
9	19.8	16.0	1.9
10	21.0	16.9	1.9
11	22.0	17.6	2.0
12	23.0	18.2	2.0
13	23.5	19.0	2.1
14	24.3	19.9	2.2
15	25.0	20.1	2.2
16	25.5	21.0	2.4
17	26.4	21.6	2.8
18	27.0	22.1	2.9
19	27.5	22.9	3.0
20	28.1	23.5	3.1
21	28.9	24.1	3.1
22	29.5	25.0	3.2
23	30.1	25.5	3.5
24	31.0	26.5	4.0
25	31.8	27.4	4.2
26	32.6	28.4	4.9
27	33.5	29.5	5.2
28	34.8	31.0	6.1
29	36.0	33.0	7.5
30	38.5	36.1	11.0
Total	667.6	607.8	91.6
Tristimulus	21.8	20.3	3.7
Trichromatic (%)	47.7	44.3	8.0

determinations shall be room temperature, so that condensation and gas expulsion will not interfere with the light transmission. The light transmission data shall be determined with 10-mm. absorption cells.

The result of color determinations shall be expressed as follows:

Classification	Units	Record to Nearest
Dominant wavelength	Millimicrons	Unit
Luminance	Per cent	0.1 per cent
Purity	Per cent	Per cent

1. Apparatus

1.1. Spectrophotometer. To determine the light transmission characteristics of a solution, a spectrophotometer shall be used. The instrument shall have 10-mm. absorption cells, a 5-mm. spectral band width, and an effective operating range from 400 to 700 millimicrons.

1.2. Two 250-ml. filtering flasks with side tubes. Glassware must be thoroughly cleaned and rinsed before each use.

1.3. Walter crucible holder.

1.4. Micro metallic filter crucible with a 40-micron average pore size.

1.5. Calcined filter aid, equivalent to Johns-Manville Celite No. 505.

1.6. Vacuum system.

2. Preparation of the Sample

Two samples shall be used, one at the original pH value of the waste and the other at pH 7.6. The latter sample shall be adjusted to pH 7.6 with concentrated H_2SO_4 or NaOH as necessary. Both samples shall be brought to room temperature prior to filtration. Samples containing large quantities of suspended material shall be centrifuged prior to filtration. The amount of filter aid used shall be 0.09 grams per square inch of filtering medium. The necessary amount of filter aid shall be added to 50 ml. of the waste and, after a thorough mixing, the slurry shall be passed through the filtering crucible with a vacuum of approximately 5 in. of mercury. The resulting filter cake shall be added to an additional 25 ml. of the waste and this slurry will again be filtered. During this filtration cycle, waste shall be added continually; when the filtrate is clear the vacuum shall be released and the crucible holder and crucible transferred to a clean flask. The vacuum shall again be increased slowly to approximately 5 in. of mercury and 30 ml. of the filtrate shall be collected for a color determination.

3. Light Transmission Characteristics

The 10-mm. absorption cells shall be thoroughly cleaned and rinsed with distilled water. The absorption cells shall then be rinsed twice with the filtered waste and the external transmission surfaces cleaned with lens paper before filling for the transmission determinations. The transmission data shall be determined by the selected ordinate method (3) and at the visible spectrum wavelengths shown in Table I. Distilled water shall be used as the blank in these determinations. The transmittancy values (per cent) obtained at the selected wavelengths for the primaries (X, Y, and Z) in Table I shall be added and multiplied by the appropriate factors to give the tristimulus values (3) X, Y, and Z. The tristimulus value Y is the luminance of the sample directly as per cent. Each of the tristimulus values shall be divided by the sum of the tristimulus values (X, Y, and Z) to give the trichromatic coefficients (3) x, y, and z. The dominant wavelength and purity values shall be determined by locating the intersection of the trichromatic coefficients x and y on the chromaticity diagram (Figure 5).* The area VCR in Figure 5 includes the purple region, and the dominant wavelength shall be ex-

* If more accurate values are desired, larger charts are presented in Hardy's "Handbook of Colorimetry" (3).

pressed as the wavelength of the complimentary color value followed by the letter "c." This value may be determined by passing a straight line from the x, y point through C to the point of intersection with the elliptical border line.

The following dominant wavelength ranges provide a guide for the corresponding spectrum colors:

Wavelength Range (mμ.)	Color
400 to 465	Violet
465 to 482	Blue
482 to 497	Blue-green
497 to 530	Green
530 to 575	Greenish-yellow
575 to 580	Yellow
580 to 587	Yellowish-orange
587 to 598	Orange
598 to 620	Orange-red
620 to 700	Red
400 to 530c	Blue-purple
530c to 700	Red-purple

Acknowledgment

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RATES AND RATE STRUCTURES FOR WATER AND SEWAGE WORKS

Joint Committee Report Available

Reprints of "Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works" are now available from the Federation headquarters office. The 126-page report is a joint effort of committees of the American Society of Civil Engineers and the Section of Municipal Law of the American Bar Association together with representatives of the American Water Works Association, the National Association of Railroad and Utilities Commissioners, the Municipal Finance Officers Association, the Federation of Sewage Works Associations, the American Public Works Association, and the Investment Bankers Association of America.

In addition to reviewing the factors involved in financing privately-owned and publicly-owned utilities and in determining annual revenue requirements, the report reviews present practices in raising total annual revenue for water and sewage works and recommends procedures for establishing fair rates and rate structures. Also included are a review of present practices for enforcing payment of water and sewage charges and recommendations regarding this important phase of utility operation.

Reprints of the report are available at $1.00 per copy from *Federation of Sewage and Industrial Wastes Associations*, 325–26 Illinois Building, Champaign, Illinois.

WASTE TREATMENT DEVELOPMENTS IN THE GENERAL ELECTRIC COMPANY *

By Kenneth S. Watson

Coordinator of Waste Treatment, General Electric Company, Schenectady, N. Y.

Recognizing the tremendous value of the nation's surface water resources and the responsibility of all users of these resources to conserve and protect them to the maximum reasonable extent, the General Electric Company has inaugurated a companywide program of industrial waste control and treatment. Because the plants are widely scattered geographically, it is the philosophy of top management that existing plants with pollution problems will be responsible for their solution. The company is providing technical counsel, however, to all plants, in the direction of making the best waste treatment "know how" in the field available to them. It will be the further responsibility of management to make waste treatment experience and techniques which are in use or have been developed in one branch of the company available to any plants where they might apply. Personnel at Executive Department level will also be concerned with encouraging the individual plants to take care of their community responsibilities in the pollution control field, but that these responsibilities be met in the most economical manner.

The General Electric Company expects to keep its pollution problem from becoming more serious by planning and constructing waste control and treatment facilities as new plants or plant additions are planned and constructed. Personnel at company level have the responsibility of seeing that industrial wastes are not overlooked in new construction projects.

Four-Phase Program

Top management has adopted a program in which the individual plants are taking pollution control action as outlined in four major phases, as follows:

1. Determining whether a pollution problem of consequence exists and defining that problem where necessary. Where a problem appears to exist, a survey to determine the quantity of wastes being discharged and their characteristics will be made by plant personnel. This survey will involve gaging the flow of the effluent, as well as sampling and analyzing the waste over a sufficient period of time to determine what pollution load it carries.

2. Taking all economical steps short of treatment to reduce the pollution load. In this phase the use of care, good housekeeping principles, recovery, segregation, conservation, process change, and repiping will be exhausted. This phase will be prosecuted to the maximum extent, because in most cases it represents the simplest and cheapest means of coping with the problem.

3. Designing, constructing and operating the waste treatment units to correct the problem. Phase three is self-explanatory and phases one and two are logical preliminary steps to it. The information obtained in phase one will permit the design of a sound waste treatment plant. Consulting engineer

* Presented at 1951 Joint Meeting, New York Sewage and Industrial Wastes Assn. and New England Sewage Works Assn.; Springfield, Mass.; June 7–8, 1951.

aid will often be obtained in designing treatment facilities.

4. Promulgating an educational program for company personnel. In the educational program the importance of pollution control will be covered. All the points already mentioned concerning the reduction of the problem to a minimum will also be stressed. This phase will acquaint plant personnel with the part which they must play in reducing stream pollution.

Inasmuch as the quantity of wastes being discharged by a plant is generally directly related to water consumed, the water usage picture will be investigated at the same time that the wastes are under study. The plants will be encouraged to adopt a water supply program which will:

1. Permit the use of the most suitable source of water from the standpoint of cost, quantity, and quality.

2. Encourage the recirculation and reuse of all water of proper quality for which it is economical to take such action.

3. Establish minimum quantities of water necessary to do each particular job and insist that the plant operate on this minimum plus a reasonable safety factor.

Recent Installations

In addition to outlining the pollution control program adopted by the company, some recent installations and treatment units now being planned may be of interest.

Erie Works

Consistent with the Pennsylvania clean streams program, the company recently placed in operation at Erie, Pa., a large treatment plant to condition metal finishing wastes before dis-

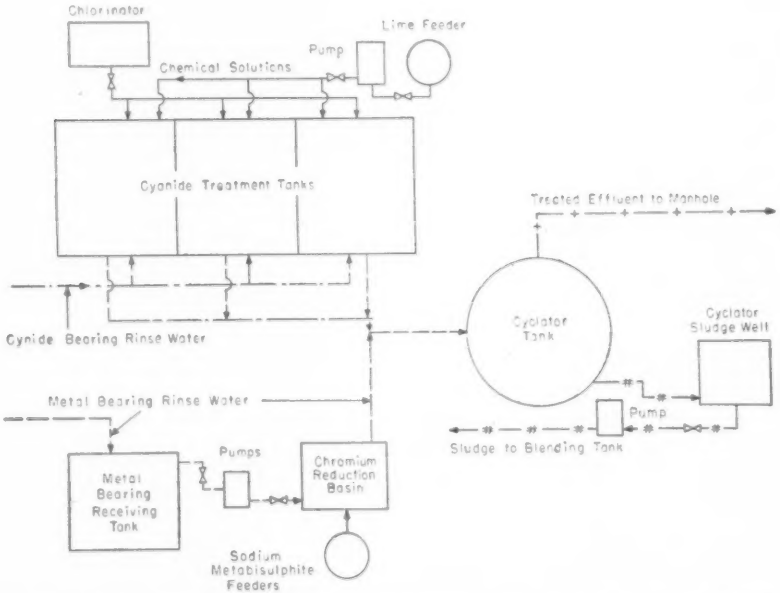

FIGURE 1.—Flow diagram of cyanide rinse-water treatment at Erie, Pa., works of General Electric Company.

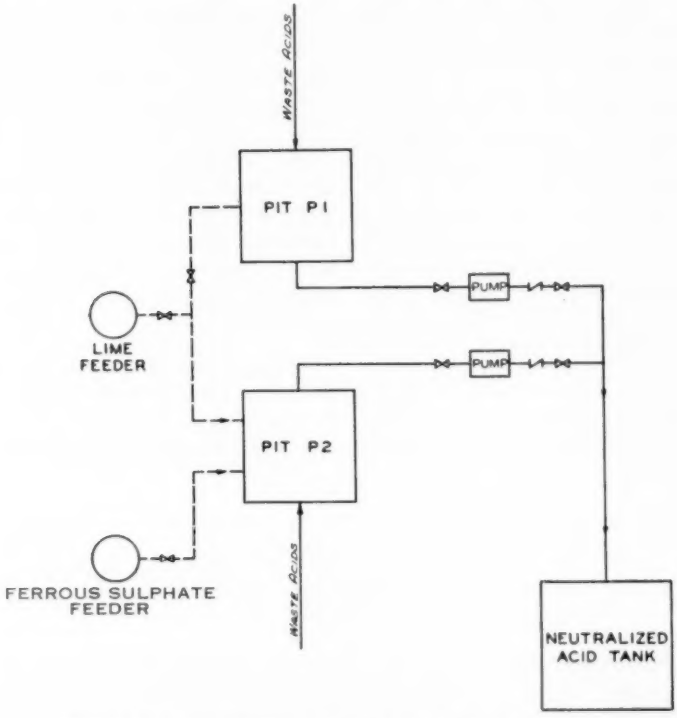

FIGURE 2.—Flow diagram of spent acid treatment at Erie works.

charging them into Lake Erie. This is the General Electric Company's largest waste treatment installation. The cost of building the plan, including the collection system, amounted to approximately $1,000,000. Four separate collection lines have been provided throughout the plant to permit the various types of wastes to be segregated and bring them under complete control. These separate lines and the acid-resistant materials required in the construction of some of them have added greatly to the costs of the treatment system at Erie.

Flow diagrams for the Erie treatment plant are shown in Figures 1, 2, and 3. In Figure 1 it will be observed that the cyanide rinse waters, which are collected in a separate system, are batch oxidized in one of three treatment tanks. Chlorine is used as the oxidizing agent after the pH has been properly adjusted with lime.

The metal-bearing rinse waters, including those containing chromium, are also segregated. The chromium is reduced to the trivalent form by the use of sodium metabisulfite or ferrous sulfate after the pH is adjusted, if necessary. The oxidized cyanide wastes and the reduced chromium wastes are then both discharged into the cyclator for supplementary pH adjustment to permit most of the metal ions to be precipitated and the treated effluent to become practically neutral before discharge into Lake Erie.

The concentrated acids from the plant are conveyed in a separate system into neutralization tanks (Figure 2). In these tanks lime is used to neutralize the acid. A portion of the acids carrying chromium is treated with ferrous sulfate to convert the chromium to the trivalent form. The sludge produced by the neutralization reaction is pumped to a blending tank (Figure 3), where it is blended with the sludge from the Cyclator. The final sludge produced is then vacuum filtered after use is made of fly ash as a filtering aid.

This plant has been in operation for less than two months, so proven performance results are not yet available.

Brockport Plant

The Brockport, N. Y., plant was taken over by the General Electric Company and placed in operation in 1949. In accordance with the New York stream pollution control program, waste treatment facilities were provided to remove the metal ions and neutralize the acid before the wastes are discharged into a barge canal. The three drainage systems in operation at Brockport are:

1. Clean water for direct discharge into the canal without treatment.
2. Chromium and nickel rinse waters.
3. Acid and alkaline rinse waters.

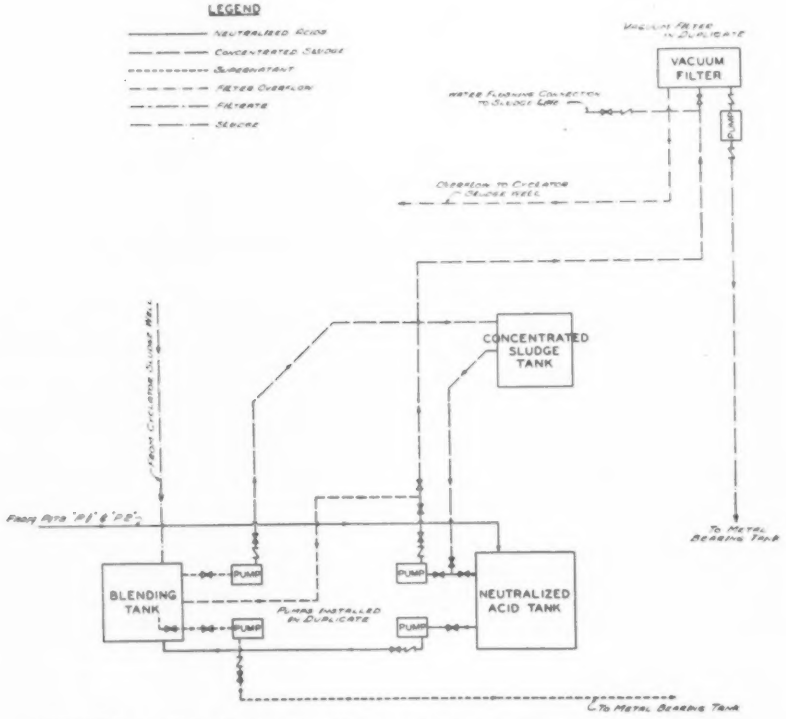

FIGURE 3.—Flow diagram of acid waste and sludge conditioning at Erie works.

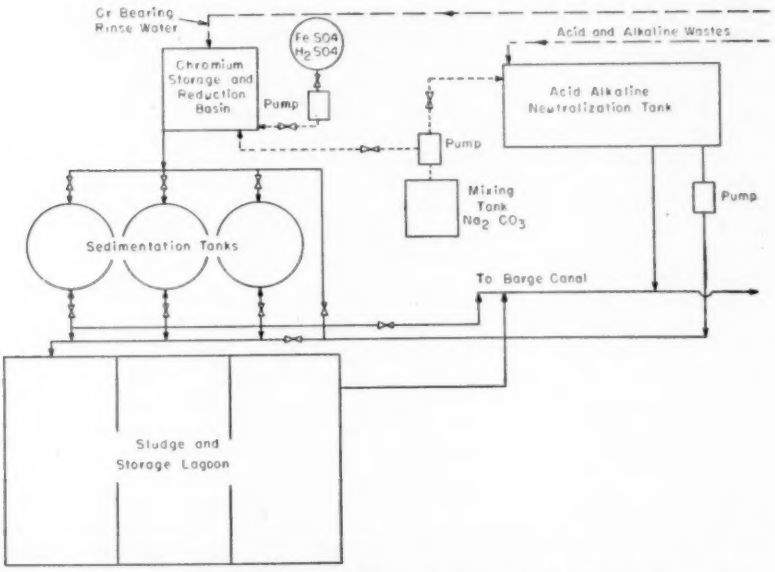

FIGURE 4.—Flow diagram for treatment of metal ions and acid wastes at Brockport, N. Y., works.

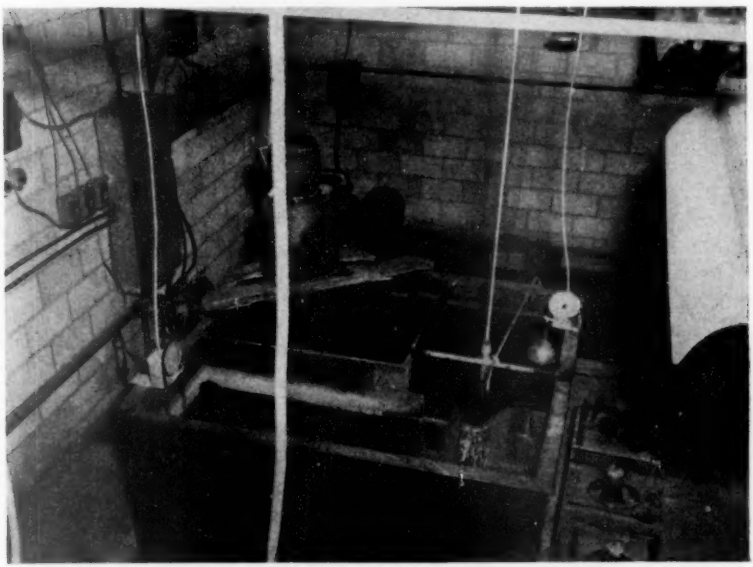

FIGURE 5.—Tank for reduction and neutralization of chromium rinse water at Brockport works.

As shown in the flow diagram (Figure 4), the chromium in the rinse water is reduced to the trivalent form by pH control and treatment with ferrous sulfate. This reduction is accomplished in a compartmented tank equipped with an agitator (Figure 5). Soda ash is fed into the last compartment of the tank and the sludge is removed in one of the three sedimentation tanks. The sludge is discharged into the sludge lagoon and the supernatant into the barge canal.

The acid-alkaline rinse waters are conveyed into a baffled neutralization tank (Figure 6) for proper neutralization with supplementary acid or alkali. The chemical feeders for this tank are activated by an automatic pH meter; thus, the pH of the effluent is automatically kept slightly on the alkaline side. The sludge from this tank can be pumped to one of the sedimentation tanks for further settling or it can be pumped directly to the sludge lagoon. The neutralization tank is also rigged so that if it should be overloaded or something goes wrong with the chemical feeders, the wastes cannot go to the canal, but will be pumped to the sludge lagoon.

The sludge lagoon is equipped with three overflow dams. Thus, most of the sludge accumulates in the upper compartment of the lagoon.

Philadelphia Works

In Philadelphia, Pa., the city has required for a number of years that the General Electric Company neutralize its wastes to a pH of 5 before discharging them into the municipal sewer system. This is accomplished by partially equalizing the acid discharge from the plant and passing it through two upflow limestone filters connected in series. This system functions as outlined in Figure 7. Filtered effluent in

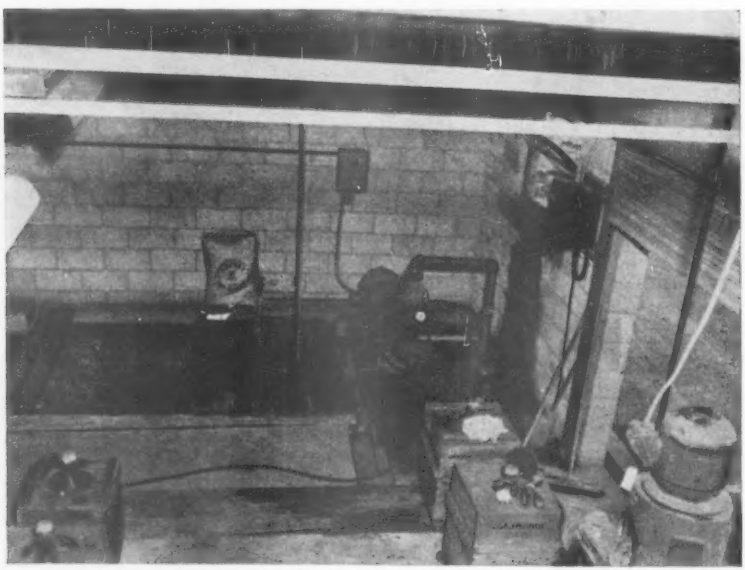

FIGURE 6.—Neutralization and equalization tank for acid and alkaline rinse waters at Brockport works.

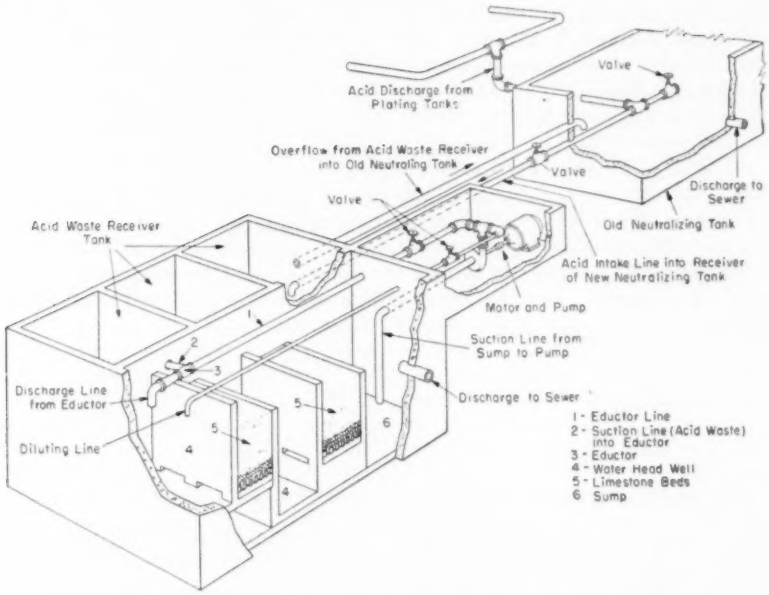
Acid Discharge from Plating Tanks
Valve
Overflow from Acid Waste Receiver into Old Neutraling Tank
Valve
Valve
Discharge to Sewer
Old Neutralizing Tank
Acid Waste Receiver Tank
Acid Intake Line into Receiver of New Neutralizing Tank
Motor and Pump
Suction Line from Sump to Pump
Discharge Line from Eductor
Discharge to Sewer
Diluting Line
1 - Eductor Line
2 - Suction Line (Acid Waste) into Eductor
3 - Eductor
4 - Water Head Well
5 - Limestone Beds
6 Sump

FIGURE 7.—Sketch of acid neutralization tank facilities at Philadelphia works.

a proportion of about 2 to 1 is picked up by the pump shown and pumped through an eductor, which brings the untreated acid to the filter. By this means recirculation is accomplished and the necessity of providing and maintaining a pump to handle the concentrated acid is avoided. Limestone crushed to rice size is used in the filter.

Proposed Waste Treatment

A major collection and treatment system has been designed for the Trenton, N. J., plant of the General Electrical Company. Further action on this plant is awaiting the completion of a resurvey of the waste problem by plant personnel to verify treatment unit sizes. This resurvey was occasioned by production changes.

The new system will consist of the following separate collection lines:

1. Concentrated acid.
2. Concentrated alkali.
3. Cyanide rinse water.
4. Metal-bearing rinse water, including chromium.
5. Acid and alkali rinse waters.

The system consists of a cyanide chlorination unit and a chromium reduction unit. The effluents of these two systems will flow into an equalization basin, which will also receive the acid-alkali rinse water. This basin will be rigged for agitation and with feeders for supplementary acid and alkali. Neutralization will be accomplished in this basin before the treated wastes are discharged into the township sewer system.

The company's Lockland, Ohio, plant is being greatly expanded. The necessary waste treatment system has been discussed with city and state offi-

cials. This system will be similar to the one being planned at Trenton. The plant effluent after pretreatment will be discharged into a county sewer system, which discharges into the Cincinnati municipal system.

A large appliances part plant is being planned near Louisville, Ky. Agreement has been reached with city and state officials here concerning a pretreatment plant of the Trenton type. The effluent from this system, which will be designed as the other plant facilities are being designed, will discharge into the Louisville sewer system.

Acknowledgments

Appreciation is expressed here to the personnel working on waste treatment in the individual plants and to the consulting engineers who have been employed to design treatment units, for aid furnished in compiling the information used in this paper.

PLATING-ROOM CONTROLS FOR POLLUTION ABATEMENT

An eminently practical 20-page manual on "Plating-Room Controls for Pollution Abatement" has been published by the Ohio River Valley Water Sanitation Commission. The extremely readable guidebook of principles and practices for curbing losses of solutions and metals that might otherwise find their way into watercourses is a reference data publication compiled by the Metal-Finishing Industry Action Committee of the Commission.

The manual—written in plating-room parlance by leaders in the metal-finishing field—comes directly to the point in giving methods for saving critical materials. As a matter of particular interest to management of metal-finishing plants, it emphasizes many factors involved in cutting operation costs, stressing the fact that treatment of waste is expensive, whereas control of waste is profitable.

The major principles of good housekeeping stressed in control of polluting wastes include:

1. Reduction of dragout losses by proper drainage and re-use of rinse waters.
2. Effective rinsing through proper rinse tank design and operation, efficient sprays, and clean racks.
3. Prevention of leaks and spills.
4. Purification of contaminated processing baths so that they can be reused.
5. Sale or exchange of baths that cannot be purified.

Installation of waste treatment facilities is recommended only after all measures to reduce the quantity and strength of the plant's waste have been explored. It is pointed out that the need for and elaborateness of treatment facilities will depend on the effectiveness of the waste reduction program. Diagrams of suggested dragout reduction and rinsing schemes are included.

Copies of the manual can be obtained by writing to: Edward J. Cleary, executive director, Ohio River Valley Water Sanitation Commission, 414 Walnut St., Cincinnati 2, Ohio.

DETERMINATION OF DISSOLVED OXYGEN IN INDUSTRIAL WASTES BY THE WINKLER AND POLAROGRAPHIC METHODS *

By M. C. Rand and H. Heukelekian

Introduction

The importance of accurate determinations of dissolved oxygen in the field of sewage and waste treatment can hardly be questioned. Dissolved oxygen measurements are employed in the standard B.O.D. test, in control of the activated sludge process, and in studies of stream pollution, to mention only a few of the most obvious applications. In addition to these more common uses, the test finds a host of specialized applications in research.

The ever-increasing production of industrial wastes, their consequent occurrence in natural waters and sewage, and especially the current increase of interest in their treatment, have given rise to the question of how such wastes affect the accuracy of the standard methods used for determination of dissolved oxygen in water and sewage. Where interferences exist, the problem of minimizing or eliminating them presents itself. The literature contains some references to the effect of sewage and certain of its constituents upon the determination of dissolved oxygen, but the effects of industrial wastes as such have been the subject of little experimentation.

The purposes of this study are, therefore, first, to evaluate the errors to which the Winkler method is subject in the presence of certain typical wastes, and second, to develop an alternate method for use when the Winkler method is inapplicable.

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Methods

The accuracy of the dissolved oxygen determinations in the presence of wastes was tested by the following procedure: Several liters of the waste in question were boiled to remove dissolved oxygen, and cooled under nitrogen. Various dilutions of the waste were then prepared with distilled water of known dissolved oxygen content. Each sample was analyzed immediately after preparation, the analytical results being compared with the theoretical concentration calculated from the dissolved oxygen content of the dilution water. The waste, after being boiled, was assumed to be completely free of dissolved oxygen.

The sodium azide modification of the Winkler method was employed. In the presence of industrial wastes, the samples were alkalinized for only 15 seconds. All "observed" values listed in the tables are averages of three or more replicate determinations.

Accuracy of Winkler Method in Presence of Industrial Wastes

The observed and calculated D.O. values and the percentage recovery of various dilutions of 7 industrial wastes are given in Table I.

The data of Table I plainly show that industrial wastes of many different types cause serious errors in the determination of dissolved oxygen by the Winkler method. In general, the errors tend to increase with increasing waste concentration, as might have been expected. There is no correlation among the various wastes, and indeed none would have been anticipated, as

TABLE I.—Accuracy of the Winkler Method in the Presence of Industrial Wastes

Waste		Dissolved Oxygen		
Type	Conc. (%)	Expected (p.p.m.)	Observed (p.p.m.)	Recovery (%)
Penicillin stripper bottoms	1	7.9	7.3	92
	5	7.6	6.1	80
	10	7.2	4.8	66
	25	6.0	1.7	28
	50	4.0	0.0	0
Titanium	1	7.8	6.8	86
	5	7.5	2.2	29
	10	6.4	0.0	0
Sulfite liquor	0.033	7.2	7.0	97
	0.10	7.2	6.4	89
	0.33	7.2	4.7	65
	0.5	7.2	3.8	53
	1.0	7.1	1.6	23
	5	7.6	0.0	0
	10	7.2	0.0	0
Dairy	100	0.0	4.6	—
Laundry	1	8.1	8.7	107
	5	7.7	8.4	109
	10	7.3	7.8	107
	25	6.1	7.4	121
	50	4.1	6.7	163
	100	0.0	5.7	—
Packinghouse	1	7.5	7.6	101
	5	7.2	7.4	103
	10	6.8	7.3	107
	25	5.7	7.3	128
	50	3.8	6.2	163
	100	0.0	5.1	—
Metal plating	1	5.9	6.0	101
	5	5.7	5.9	103
	10	5.5	5.7	104
	25	4.5	5.2	116
	50	3.0	4.4	147
	100	0.0	2.6	—

the wastes differ so greatly in composition.

The occurrence of errors, such as those indicated in Table I, does not necessarily imply that the Winkler method is totally invalid for use in the presence of industrial wastes. It is even conceivable that for certain purposes it may be possible to use the Winkler method at wastes concentrations known to cause interference, provided the interference is recognized and considered when the results are interpreted. However, it seems quite apparent that data such as those of Table I should serve as a warning that when industrial wastes are known to be present, any results obtained by the use of the Winkler method should be interpreted with caution.

The Polarographic Method

In a search for possible means for reducing the interferences of industrial wastes in the determination of dissolved oxygen, the polarographic method was considered. Vitek (1) had pointed out in 1933 that such a determination is possible; since that time the polarograph has been employed for determining dissolved oxygen in a variety of systems. What recommended this technique particularly for the work reported herein was the fact that means for eliminating most interferences appeared to be inherent in the method. It was decided, therefore, to evolve a method of determining dissolved oxygen polarographically, and to test the accuracy of this method in solutions containing industrial wastes by the same method used for testing the Winkler method.

Development of the Method

Concentration of Maximum Suppressor

When the polarograph is used for the determination of dissolved oxygen, it is necessary to add to the solution a small amount of some surface-active material. In the absence of such substances, the diffusion current of dissolved oxygen does not show a smooth, regular increase with increasing applied potential, but rises instead to a pronounced maximum at about the voltage where a current plateau is expected. Methyl red was selected as the compound for use in this work because of its ready availability and ease of preparation.

The current-voltage curve of dissolved oxygen in distilled water was

observed at 0, 5, 10, and 15 p.p.m. of methyl red, to determine what concentration of the dye was required for effective maximum suppression. The results are shown in Figure 1, which indicates that 15 p.p.m. are necessary for complete elimination of the maximum.

Selection of Analytical Procedure

In most previous applications of the polarograph to the determination of

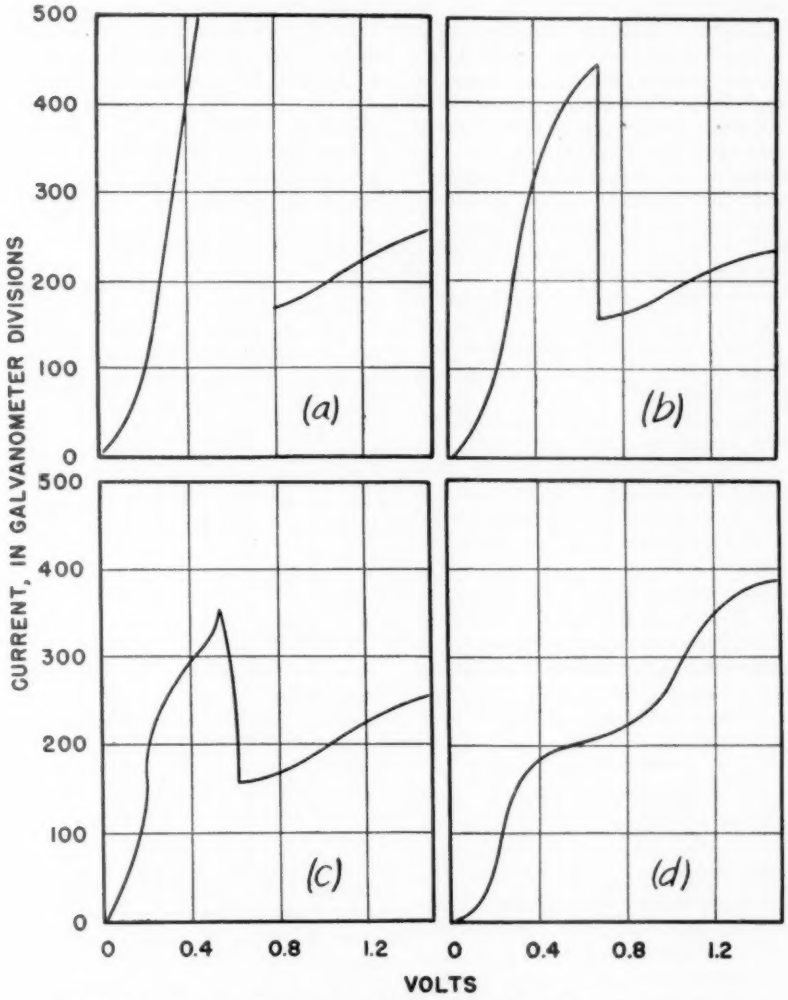

FIGURE 1.—Comparative current-voltage curves for D.O. in distilled water with:
(a) 0 p.p.m. methyl red.
(b) 5 p.p.m. methyl red.
(c) 10 p.p.m. methyl red.
(d) 15 p.p.m. methyl red.

dissolved oxygen, the workers have used either single current readings at one applied potential (5) (6) (7) (8) or the difference between the readings at two potentials (3) (4) as the index of dissolved oxygen concentration. The single reading technique was not considered desirable for use in the presence of industrial wastes, because the magnitude of such a reading would be proportional not to the concentration of dissolved oxygen alone, but to the total concentration of all the substances present which react at the cathode at a potential equal to or lower than that applied. Industrial wastes may contain considerable amounts of such interfering substances. Likewise, the difference in current reading between any two applied potentials is not specific for dissolved oxygen, but will include all substances whose half-wave potentials lie between the two selected voltages.

The procedure finally adopted was that of Seaman and Allen (10). A current reading is taken at one potential. The dissolved oxygen is then swept out of the sample by a stream of inert gas, and a second reading is taken at the same potential. The original concentration of dissolved oxygen is determined from the change of current occasioned by its removal. This technique eliminates many of the interferences to which the previously mentioned methods are subject.

Selection of Operating Voltage

For analytical purposes, it is desirable to use a potential at which the current changes as little as possible with changes of applied voltage. This minimizes errors due to slight inaccuracies in setting the electrode potential. The plateau after the first wave of current increase appearing in Figure 1d is preferable to the higher plateau, because, as shown by Moore, Morris, and Okun (8), the position of the second plateau has a tendency to shift with the dissolved oxygen concentration.

The potential selected for general use in this work was 550 millivolts between the dropping electrode and the mercury pool, which corresponds to the first plateau of Figure 1d. It should be emphasized that this potential will not be suitable for use with any and all instruments, as the potential of the pool with respect to a standard electrode will differ from one instrument to another. It is advisable to construct a current-voltage curve and select the operating voltage separately for each instrument.

Effect of Temperature

The temperature coefficient of the diffusion current has been reported as 1.6 per cent per degree Centigrade (8) and as 1.4 per cent per degree Centigrade (10) in various types of solution. The value 1.4 per cent per degree is more nearly accurate for most industrial wastes. The formula for converting the observed difference in galvanometer reading, ΔG_o, to that corresponding to a standard temperature, t_s, is

$$G = 0.014\ (\Delta G_o)\ (t_s - t) + (\Delta G_o) \quad (1)$$

Standardization

Seaman and Allen (10) recommend determining the relationship between dissolved oxygen concentration and current at one point only, and assume that the relationship is linear under their conditions. However, in the present studies it has been found that when methyl red is used as the maximum suppressor, the conductivity of the solutions is low enough so that the diffusion current is not always a perfectly linear function of dissolved oxygen concentration. Therefore, it is considered advisable, when using this technique, to construct a calibration curve containing a number of points.

The following method of calibration was used in this study. Several liters

TABLE II.—Accuracy of the Polarographic Method in the Presence of Industrial Wastes

Waste		Dissolved Oxygen		
Type	Conc. (%)	Expected (p.p.m.)	Observed (p.p.m.)	Recovery (%)
Penicillin stripper bottoms	1	7.4	7.4	100
	5	7.1	7.2	101
	10	6.7	7.2	108
	25	5.6	6.1	109
	50	3.7	3.1	84
	100	0.0	0.5	—
Titanium	1	7.4	7.9	107
	5	7.2	7.8	108
	10	6.8	7.8	115
	25	5.9	7.2	122
	50	4.4	5.3	120
	100	0.0	0.5	—
Sulfite liquor	1	7.4	7.0	95
	5	7.2	7.6	106
	10	6.8	7.2	106
	25	5.8	5.6	97
	50	3.8	2.9	76
	100	0.0	0.5	—
Laundry	1	7.6	7.5	99
	5	7.3	7.2	99
	10	6.9	5.6	81
	25	4.9	3.1	63
	50	3.6	2.0	56
	100	0.0	0.2	—
Dairy	1	8.0	8.0	100
	5	4.5	4.2	94
	10	4.1	4.0	97
	25	3.4	3.2	93
	50	2.3	2.1	91
	100	0.2	0.2	—
Packinghouse	1	7.2	7.5	104
	5	7.0	7.4	106
	10	6.6	6.5	98
	25	5.9	5.9	100
	50	4.2	4.3	102
	100	0.0	0.4	—
Metal plating	1	7.6	7.7	101
	5	7.3	6.5	89
	10	6.9	6.3	91
	25	5.55	5.2	94
	50	3.7	3.7	100
	100	0.0	0.0	—

of 0.01N KCl were prepared. A sample was removed by siphoning, and the dissolved oxygen was determined by the Winkler method. A second sample was taken in a pipette and used to determine the diffusion current at 550 mv. before and after deaeration. The concentration of dissolved oxygen in the stock solution was then changed by bubbling air or nitrogen through it, and samples were again taken for the two methods of analysis. This process was repeated until a set of points was obtained which covered the desired range of dissolved oxygen in steps not greater than about 1 p.p.m. The temperature of each sample analyzed polarographically was taken before its analysis. The current readings were then corrected to a standard temperature in accordance with Eq. 1, and the corrected values were used for preparation of a standard curve. This process had to be repeated whenever a new capillary was installed in the instrument.

Accuracy of Polarographic Method in Industrial Wastes

Samples of diluted industrial wastes containing known concentrations of dissolved oxygen were prepared as described under "Methods." The results of their analysis by the polarographic method are shown in Table II.

Precision

Moore, Morris, and Okun (8) state that the precision of the polarographic method for dissolved oxygen varied from ± 0.03 p.p.m. below 5 p.p.m. to ± 0.25 p.p.m. above 25 p.p.m. Sea-

TABLE III.—Precision of the Polarographic Method

Sample No.	D.O. (p.p.m.)
1	3.61
2	3.53
3	3.61
4	3.53
5	3.58
6	3.61
7	3.49
8	3.67
9	3.58
10	3.61
Av.	3.58

man and Allen (10) found standard deviations of from ± 0.012 to ± 0.11 p.p.m. at concentrations from 0.12 to 12.9 p.p.m. of dissolved oxygen.

The precision was rechecked in the present study by analyzing 10 separate portions of a 0.01N KCl solution. The results are shown in Table III. The mean concentration of dissolved oxygen was 3.58 p.p.m., the maximum deviation from the mean ± 0.09 p.p.m., and the standard deviation 0.057 p.p.m.

Interferences

Gaseous or volatile oxidants stronger than oxygen will cause errors in the determination by the technique as described, because they will react at the cathode at the voltage used and will also be removed from the solution along with dissolved oxygen. The most frequently encountered substance of this type is chlorine.

Certain heavy metal ions, and also high concentrations of soaps or detergents, distort the current-voltage relationship characteristic of dissolved oxygen. This effect may result in errors in the determination, especially when the strength of the waste is varied. Fortunately, however, interferences of this type can often be reduced by selecting the operating potential on the basis of the distorted current-voltage curve, as described in the next section.

Seaman and Allen (10) also state that cyanide and sulfide cause interferences in the method. The mechanism of such interferences is not explained.

Reduction of Interferences

As shown by Table II, laundry waste causes especially great errors in the determinations when the operating potential is selected from examination of the normal current-voltage

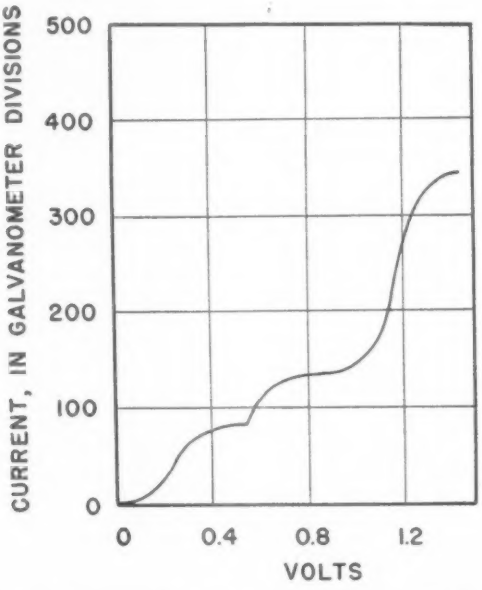

FIGURE 2.—Current-voltage curve of D.O. in laundry waste for selection of best voltage.

TABLE IV.—Accuracy of the Polarographic Method in Laundry Waste at Optimum Applied Potential

Waste Conc. (%)	Dissolved Oxygen		
	Expected (p.p.m.)	Observed (p.p.m.)	Recovery (%)
1	7.8	7.6	97
5	7.6	7.7	101
10	7.2	7.6	105
25	6.0	5.9	98
50	4.0	4.3	107
100	0.0	0.0	—

curve. It had been observed that the current-voltage curve of dissolved oxygen was distorted by high concentrations of soap, and it was considered probable that this effect was responsible for the errors. Therefore, it was considered possible that use of an electrode potential determined from the current-voltage curve of dissolved oxygen in laundry waste might improve accuracy.

A sample of laundry waste containing dissolved oxygen was placed in the cell of the polarograph, and current readings were taken at 50-mv. intervals from 0 to 2.25 volts. The sample was then deoxygenated by bubbling nitrogen through it for 5 min. The gas tube was raised above the level of the liquid, and nitrogen was passed over the surface of the sample while a second set of current readings was taken, using the same potentials as in the first set. Plotting the differences between the two sets of readings gave the curve of Figure 2.

From Figure 2, 900 mv. was selected as the best voltage for use in the presence of laundry waste. The accuracy of the determination at this potential was tested by the method used in previous accuracy tests. The results are shown in Table IV.

Comparison of Table IV with Table II shows that, in the case of laundry waste, a great improvement of accuracy was effected by the technique of determining the operating voltage in the waste itself. However, it should not be concluded that this procedure is a panacea for all the interferences which may occur in the polarographic determination of dissolved oxygen. For example, a similar experiment with titanium waste showed that no improvement of accuracy resulted from use of the voltage determined in the waste.

Effect of Exposing Samples to Air

In the technique employed in this study, the sample is exposed to air during the analysis. To determine what error was introduced by this practice, the effect of exposure to air was determined by placing a sample of partly deoxygenated 0.01N KCl in the cell of the instrument, and observing the galvanometer deflection from time to time. After readings had been taken for one hour, the sample was completely deoxygenated by bubbling nitrogen through it, so that the changes of galvanometer reading which had occurred during an hour's exposure to the air might be converted to changes of dissolved oxygen concentration in the sample. The results of this experiment are shown in Table V.

Table V shows that the change of dissolved oxygen concentration is within the limits of experimental error for exposures up to 10 min. As the time required to obtain the initial galvanometer reading is 30 to 40 sec., it does not appear that special precautions to protect the sample from air are required.

TABLE V.—Effect of Exposure to Air

Time (min.)	D.O. (p.p.m.)	Time (min.)	D.O. (p.p.m.)	Time (min.)	D.O. (p.p.m.)
0	3.74	6	3.78	35	4.68
1	3.74	10	3.81	40	4.70
2	3.78	15	3.96	45	4.90
3	3.78	20	4.08	50	5.00
4	3.78	25	4.40	55	5.27
5	3.78	30	4.58	60	5.44

There is some possibility of aeration of the sample while it is being introduced into the cell of the instrument. However, judging from the data of Table II, the accuracy of the determination does not suffer materially so long as ordinary precautions are taken to minimize such aeration.

Discussion

Comparison of Table I with Tables II and IV shows that in most cases the polarographic method gives recoveries closer to 100 per cent than does the Winkler method, particularly at the higher concentrations of waste.

Laundry waste causes considerable errors in the polarographic method when the operating potential is selected in accordance with the normal current-voltage curve of dissolved oxygen. However, these errors may be largely eliminated by determining the operating potential on the basis of the distorted current-voltage curve applying when laundry waste is present.

The case of metal plating waste is of interest. It appears from the tables that at 5 and 10 per cent waste concentration the accuracy of the Winkler method is greater than that of the polarographic method. Probably it is the precision, not the accuracy, of the polarographic method that is affected by the presence of this waste. Metal plating waste has a high conductivity and contains ions producing a high blank current at the potential used for measurement of dissolved oxygen. The diffusion current of dissolved oxygen, therefore, becomes a relatively small fraction of the total current and less exactness is possible in its determination than in some other cases.

In general, then, the polarographic method presents a means of obtaining reasonably accurate determinations of dissolved oxygen, even at concentrations of industrial wastes causing very serious errors in the Winkler method.

Conclusions

The presence of industrial wastes causes errors in the Winkler method for dissolved oxygen determination. In some cases these errors are very serious. However, the method may still be applicable for certain purposes when industrial wastes are present, but only if the resulting errors are recognized.

Use of the polarographic method permits reasonably accurate determinations of dissolved oxygen, even under conditions which render the Winkler method quite inapplicable.

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APPENDIX

PROCEDURE FOR DISSOLVED OXYGEN DETERMINATIONS BY THE POLAROGRAPHIC METHOD

Apparatus

Any of the commercially available polarographs may be used, or one may be constructed in the laboratory, as described by Petering and Daniels (2), Ingols (6), and Kolthoff and Lingane (12).

Reagents

KCl, approximately .01N (0.75 g. per liter).

Methyl red, 0.1 per cent. Dissolve 100 mg. of methyl red with 7.4 ml. of 0.05N NaOH and dilute to 100 ml.

Nitrogen gas.

Setting up the Instrument

The instrument should be assembled, adjusted, and tested in accordance with the manufacturer's instructions.

Determination of Operating Voltage

A. 0.01N solution of KCl is aerated for a few minutes. (Complete saturation is unnecessary.) A sample is then placed in the cell of the instrument, and the stock solution of methyl red is added to bring the final concentration of methyl red to approximately 15 p.p.m. The voltage on the dropping electrode is then varied in 0.02-v. steps from 0 to 2 v. At each voltage, the current (or galvanometer deflection) is read and recorded. It will be noted that the current increases as the mercury drop grows, then abruptly decreases when the drop falls. The maximum deflection is always taken as the reading. A graph is then drawn, using voltage as the abscissa and current as the ordinate. The resulting curve will ordinarily have the form shown in Figure 1d. The center of the plateau between the two waves corresponds to the voltage which should subsequently be used.

When working with certain wastes, one may sometimes further improve the accuracy of the determinations by determining the operating voltage, not in KCl solution, but in a sample of the waste itself, as described in the body of this paper under the heading "Reduction of Interferences."

Calibration

See "Standardization" in the body of this paper.

Analysis

The unknown sample is placed in the cell of the instrument and 15 p.p.m. of methyl red is added. The predetermined voltage is applied to the electrode, and the resulting current is noted. This part of the procedure should be executed rapidly to avoid absorption of oxygen from the air. A thermometer is inserted in the sample, and its temperature is noted. The dissolved oxygen is then removed by bubbling nitrogen rapidly through the sample for 5 min. The gas tube is lifted above the surface of the sample, and nitrogen is allowed to flow over the surface of the sample while a second current reading is taken. The difference between the two readings is corrected for temperature as described in the body of the paper, then converted to dissolved oxygen concentration with the aid of the standard curve.

OZONATION OF CYANIDE WASTES *

By Richard G. Tyler, William Maske, M. J. Westin, and Willard Matthews

Respectively, Professor of Sanitary Engineering, Research Chemist, and Research Fellows, University of Washington, Seattle, Wash.

This paper is presented as a progress report on research being carried on at the University of Washington on the ozonation of cyanide wastes. It is believed that the work has proceeded far enough to indicate, in general, the effectiveness of ozone in the oxidation of this waste. Another reason for presenting this progress report is that chlorine, which is being used increasingly in the treatment of cyanide wastes, is becoming scarcer for peacetime usages as the Korean situation continues. If, as appears possible, ozone can do the job adequately, it would have the advantage of not being affected by war priorities and so would be useful to industries wishing to do something about their cyanide waste problems during the present emergency.

Cyanide Treatment Methods

The methods now in use for treating cyanide wastes are acidification, chemical precipitation, and chlorination. Each of these methods has its advantages and also some disadvantages. With acidification, care must be taken in the disposal of the highly toxic cyanide gas evolved during the process. Also, with the increasing attention that is being focussed upon the problems of air pollution, this method is less likely to be used in the future except for locations not in populous areas. Chemical precipitation, of course, has its sludge problems and requires the attention usually essential to the successful application of this method to other industrial wastes. Chlorination has certain obvious advantages over the other treatments, but it too has some drawbacks. Accurate controls are required to carry out the process and at the same time keep down the residual chlorine in the effluent to acceptable standards. Chlorine residual is as toxic to fish as is cyanide, so that it should be held within similar limits in the treated waste. In the state of Washington, this is an important drawback to chlorination, because fishing is important both as an industry and as a sport. Large chlorine dosages also increase the pH or acidity, which may be troublesome under some conditions, as where it may attack pumps, concrete, or steel structural work, or be injurious to fish in the stream receiving the waste.

The oxidation of the cyanide to cyanate by chlorination, however, is rapid and efficient. But where it is necessary to carry the reaction farther by oxidizing the cyanate also, the process is slower and less efficient. Just what minimum residual of cyanate can be produced satisfactorily and economically with chlorination and what chlorine residual is produced in the process does not appear in the literature.

In some cases the chlorine residual may not be a very important problem, as is the case where other materials in the waste or the receiving waters are able to use up the residual. Some of the test data that have come to the attention of the authors indicate that in order to eliminate most of the

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cyanate, chlorine residuals of from 100 to 150 p.p.m. seem to be necessary, whereas the allowable limit is 1 p.p.m.

Ozonation Experiments

The authors, in using ozone with cyanide wastes, have found that it is an oxidation agent as effective as chlorine, and at the same time, one in which the residual can be more easily controlled, because water which is effectively aerated during ozonation cannot hold more than 3 p.p.m. of ozone in solution as a maximum. It has been used extensively abroad in the treatment of water supplies and has had a limited use in the United States in that field. Recent pilot plant studies (1) have indicated its advantages in treating phenolic wastes also, while other uses are now receiving serious consideration.

The experiments discussed in this paper were carried out on a cadmium cyanide solution obtained directly from one of the plating tanks of the Boeing Airplane Company, rather than on the waste discharge from the same treatment tank, as the former solution is uniform in character and therefore eliminates some of the variable components in the wastes discharged from the tanks. In several samples in which the cyanide content varied from 7.5 to 50.0 p.p.m., the pH ran from 9.25 to 10.16. These dilutions, for convenience, are hereinafter referred to as cyanide waste.

In the preliminary tests, samples of the cyanide solution or wastes were placed on a shaking machine in bottles containing the desired amounts of ozone-air mixtures, in order to determine the approximate amount of ozone required for completing the oxidation process. Thereafter, all tests were made by bubbling the ozone through the cyanide solution contained in vertical, 1⅞-in. diameter, plastic tubes. Batch and continuous flow methods were successfully employed. Ozone was produced by a laboratory generator and applied through a porous diffuser in the bottom of the column. By this method of application, the ozone was completely absorbed by the solution until the cyanide had been reduced to a mere trace. Thereafter, small quantities of ozone escaped through the air exhaust, but for some time this loss was quite small and was vented to a convenient stack.

The data from several of the earlier test runs are summarized in Table I.

The mechanism of the reactions involved in the oxidation of cyanide to nitrogen and carbon dioxide became clearer as this study progressed. A

TABLE I.—Typical Test Data on Ozonation of Cyanide Waste

Item	Test Number			
	5	6	7	8
Method of treatment	Continuous	Cont. 2-stage	Cont. 2-stage	Bottle
CN^- applied (p.p.m.)	10.7	14.7	20.6	30.0
CN^- applied (g.)	0.0535	0.0833	0.1305	
Ozone applied (g./hr.)	0.0875	0.122	0.110	
Total ozone (g.)	0.0875	0.163	0.183	
pH, start of run	9.5	9.62	9.85	9.75[1]
pH, end of run	7.65	8.08	7.90	
Time to zero CN^- (hr. min.)	1:00	1:20	1:40	Shook 30 min.
Appearance of ozone[2] (hr. min.)	0:40	1:05	None	Trace[3]
Ozone—CN^- ratio	1.63:1	1.96:1	1.40:1	3.7:1

[1] Adjusted to 12.0 with NaOH.
[2] In air exhaust.
[3] At end of test.

TABLE II.—Relationship of Ozone used to Cyanide Oxidized[1]

Application Time (min.)	C^- (p.p.m.)	pH	O_3 Used (g.)	
0	46.0	10.16	0	
5	7.0	8.2	0.0738	
8	2.8	7.5	0.118	O_3 appeared in air exhaust
10	1.15	7.47	0.148	
15	0.92	7.40	0.222	

[1] Quantity treated = 1,500 ml. at 46.0 p.p.m. CN^-.

smaller ozonator better suited to laboratory-scale experiments made greater accuracy of measurement possible. Other improvements in procedure also increased the efficiencies obtained. A second series of tests were run, therefore, to explore further the reactions taking place. The data from one of these runs are given in Table II.

Discussion

From Table II it is seen that most of the cyanide is oxidized very rapidly.

The change in reaction speed at the appearance of ozone in the exhaust air may indicate the point at which the oxidation of the cyanate begins. The pH also may have some relationship to reaction speed and possibly to the beginning of cyanate breakdown.

The ozonation appears to take place in the two steps for which the following equations can be postulated:

$$2\,KCN + 2\,O_3 \rightarrow 2\,KCNO + 2\,O_2 \quad (1a)$$

$$2\,KCNO + H_2O + 3\,O_3 \rightarrow 2\,KHCO_3 + N_2 + 3\,O_2 \quad (1b)$$

$$2\,KCN + H_2O + 5\,O_3 \rightarrow 2\,KHCO_3 + N_2 + 5\,O_2 \quad (1c)$$

From the above relationship it is obvious that in the first step one mole of O_3 is required to oxidize one mole of CN^- to CNO^- and an additional 1½ moles are required to complete the oxidation, making a total of 2½ moles.

Referring to Table II, up to the time that ozone appeared in the air exhaust —in other words, when the slower oxidation of the cyanate began (after 8 min. in Table II)—0.118 g. of O_3 had been used to oxidize 0.0648 g. CN^- (46.0 − 2.8 = 43.2 p.p.m., or 0.0648 g. CN^- in 1,500 ml.). This gives a ratio of ozone to cyanide as follows: $O_3 : CN^- = 0.118 : 0.0648 = 1.82 : 1$, as per Eq. 1a. This checks closely the 1 : 1 relationship previously stated, which is, by weight, 48 : 26 = 1.84 : 1. At the end of the test, 0.222 − 0.058 (ozone in exhaust trapped and measured) = 0.164 g. of ozone had caused the oxidation of 46.0 − 0.925 = 45.075 p.p.m. CN^- = 0.0675 g. CN^-. Therefore, $O_3 : CN^- = 0.164 : 0.0675 = 2.43 : 1$ (by weight). Had the reaction been carried to completion, this ratio theoretically should be 4.61 : 1 by weight, in accordance with Eq. 1c.

The foregoing computations and deductions are given with reservations until confirmed by additional runs now is progress.

The maximum cyanide residual permitted by the Washington Pollution Control Commission to enter the waters of the state is 0.5 p.p.m. The authors believe that proper control of the pH will bring about the practically complete oxidation to cyanate before the latter's oxidation exerts an appreciable ozone demand. This would secure the most economical use of ozone for treating the waste. Tests now in progress will determine the degree to which this objective can be attained.

One of the difficulties encountered in this research arose in the selection of a satisfactory test for determining the amount of cyanide present. Experiments using the various tests described in the literature indicated that some would not check known amounts of cyanide added to a solution. The authors' experience paralleled that described by Swope, Hattman, and Pellkofer (2), in that results were all too low. Boeing engineers with whom this difficulty was discussed recommended an improved phenolphthalin technique described by Robbie (3), which they

had used. This test was used on the study reported herein, with quantities of cyanide read with an electrophotometer calibrated with dilutions of known cyanide content. However, it was discovered that the blank used for obtaining the null reading on the electrophotometer must contain every reagent used except the cyanide for obtaining correct values, as the potassium hydroxide, for example, gave a slight color equivalent to 0.1 to 0.2 p.p.m. of cyanide. Failure to realize this in the beginning led to reporting of small cyanide residuals where none probably existed.

Conclusions

From the work done to date the following conclusions can be drawn:

1. Cyanide wastes from the metal treating industries can be satisfactorily and economically treated by ozonation.

2. The efficiency of the process is improved by holding the pH at the beginning of the treatment to 11.0 to 12.0 so that the oxidation to cyanate will be practically complete before the pH drops below 8.0.

3. Cyanide is oxidized by ozone through cyanate to nitrogen gas and bicarbonate.

4. The following steps in a treatment process are suggested:

(*a*) Adjust pH to about 12.0.

(*b*) Ozonate in any efficient manner, such as in a bubble column some 10- to 15-ft. liquid depth, to an end point where ozone appears in the air exhaust. It may be necessary also to specify as a second criterion a minimum pH, the value of which would be determined for the particular waste being treated.

5. Exhaust air from the treatment plant should be vented from the building to prevent deterioration of rubber insulation or equipment parts.

6. Plastics (Saran), wood, aluminum, copper, stainless steel, or black iron protected by asphaltic protective enamel or paint, will withstand oxidation by the ozone and should be used for parts of the plant in contact with the ozone.

Acknowledgments

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Stream Pollution

A COMPARISON OF ENTEROCOCCI AND E. COLI AS INDICES OF WATER POLLUTION *

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For many years the standard test for water pollution has been the isolation of bacteria of the coliform group. These organisms are not ordinarily pathogenic, but, because of their abundance in fecal matter, they have been considered indicative of sewage pollution. Some tests have been devised to detect pathogenic bacteria in water, but have been discarded because of the difficulty in isolating these organisms. Water may be grossly polluted with sewage without harboring disease organisms at all times. Nevertheless, all sewage-polluted water is potentially dangerous because where fecal matter exists, disease organisms may be present.

The limitations of the coliform test have been recognized for a long time, including the controversy over the sanitary significance of *Aerobacter aerogenes* and other coliform bacteria whose normal habitats are not fecal matter. The possibility of false negatives occurring in the presumptive test for coliform bacteria has been recognized and presents the danger of judging as safe a water supply that is polluted. The colon bacilli have been known to multiply in water and this may give an exaggerated index of pollution (1). Winslow has stated of water analysis: "My plea is for a fundamental re-examination of the whole problem with an open mind and with a clear view of the practical results to be obtained, and the margin of error associated with their interpretation" (2).

If a test could be devised using an organism or a group of organisms, as an index of pollution, which appear abundantly in fecal material, particularly human, but are not commonly found elsewhere, it could profitably be used as an adjunct to or substitution for the coliform test. This would seem to suggest the enterococci, as they are well-defined organisms occurring primarily in fecal material. They do not tend to multiply after removal from the intestinal tract (3) and since they are not as persistent as the coliform bacteria, their presence would seem to indicate current pollution. A test for these organisms has recently been described by Winter and Sandholzer (3). The study described herein was undertaken to make a comparative analysis of use of enterococcal bacteria to indicate pollution as measured by tests for *E. coli*.

Methods

In an attempt to evaluate the two tests of water pollution, samples were collected from the harbor at New Haven, Conn., which has a known degree of pollution (4)(5)(6). This method of analyzing natural samples, rather than pure culture samples inoculated in the laboratory, was deemed advisable, as experience has shown that great reliance should not be placed on

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the results of pure culture analyses. The behavior of coliform bacteria, when associated with other organisms, is known often to differ from their actions in pure cultures as is the behavior of enterococci (1).

The sample stations were selected to include the boundaries of the harbor and were numbered consecutively from west to east. All samples were taken in sterile, labeled, wide mouth, glass stoppered, 250-ml. bottles. All stations were collected weekly for 11 weeks during the winter months. Collections were made by wading out from shore to a depth of approximately 2 ft. and scooping the sample from about 6 in. below the surface. Stations No. 4-Waterside Dock, No. 5-Tomlinson Bridge, and No. 6-Navy Pier were sampled by lowering the uncapped bottle into the water by means of a weighted cord. The bottle was then quickly raised and stoppered.

Time elapsing between taking of the first sample and the last was approximately 1 hr. 40 min. The samples were not iced in transit because the air temperature was at all times below 7° C. On arrival at the laboratory, the samples were shaken vigorously 25 times to insure equal distribution of any organisms present. Inoculations for both tests were then made.

E. Coli Determinations

The analysis used to detect the presence of *E. coli* was that recommended in "Standard Methods" (13). Serial dilutions using three lactose broth tubes for each dilution were inoculated for each sample in the following portions: 10.0 ml., 1.0 ml., 0.1 ml., and 0.01 ml. These tubes were air incubated at 35° to 37° C. and read after 24 and 48 hr. of incubation. The presence of 10 per cent or more gas formation was considered as a positive presumptive test. A standard loopful of broth was taken from all positive presumptive tests and transferred to 2 per cent brilliant-green lactose bile broth and incubated for 48 hr. at 35° to 37° C. The presence of 10 per cent or more gas after 48 hr. of incubation was regarded as confirmatory evidence of the presence of bacteria of the coliform group.

It was thought desirable to distinguish typical *E. coli* colonies from atypical colonies in order to avoid the argument over the significance of *A. aerogenes* and to achieve what is generally considered to be a more accurate index of water pollution. To make this differentiation with minimum difficulty, Levine's eosin methylene-blue agar (Difco) was employed. It has been shown that differentiation by this agar is accurate enough for the purposes of this study in comparison with the more laborious "IMVIC" reaction (7).

All positive brilliant-green lactose bile broth tubes were streaked on Levine's E.M.B. agar and incubated for 24 hr. at 35° to 37° C. The plates were read in accordance with the criteria set forth by Levine (7). The streak plate results were recorded and the M.P.N. of *E. coli* determined from the table devised by Hoskins (8). After the first two weeks of the study, during which 20 samples were collected, the 10-ml. portion was discontinued, as this dilution was not needed in determining the M.P.N. of *E. coli* in the samples.

Enterococci Determinations

The method used for determining the presence of enterococci was that of Winter and Sandholzer as adapted by the U.S.P.H.S. in analysis of Lake Michigan (9). The portions used for the enterococci were the same as initially used for *E. coli*: that is, 10.0 ml., 1.0 ml., 0.1 ml., and 0.01 ml. These portions were inoculated simultaneously with lactose broth tubes. Three tubes in each dilution containing Enterococci Presumptive Broth (Difco) were inoculated and incubated at 45.5° C. in a water bath for 18 to

24 hr. All tubes showing acid production and turbidity were transferred to the slant-broth medium of the confirmatory test. The slant portion was Enterococci Confirmatory Agar (Difco). The broth, prepared immediately before use, was Enterococci Confirmatory Broth (Difco) with 65 Oxford units of sodium penicillin added per 100 ml. Confirmation for the presence of enterococcal bacteria consisted of fine granular turbidity in the broth, small pin point colonies on the slant, and the presence of large, ovoid, Gram-positive cocci appearing singly, in pairs, or in short chains on a Gram-stained slide. Unless all the above specifications were met, the sample was considered negative. The 0.01-ml. dilution of the sample was omitted after the second week, as no positive reactions were obtained in that dilution. The M.P.N. of organisms per 100 ml. of sample were obtained in the same manner as for *E. coli*.

Results and Analysis

In computing mean values of results obtained, geometric means were used to eliminate the influence of one excessively high or low M.P.N. value. These values for each sampling point for the 11-week period show an apparent positive relationship (see Figure 1). The maximum densities for enterococci and *E. coli* center about sampling station No. 4, with lower densities at sampling stations on either side. This result was predicted as the maximum point of pollution by a sanitary survey, as it is flanked on each side by sewage treatment plants affording only primary treatment without effluent chlorination to average flows of 19 m.g.d. and 9.7 m.g.d.

A straight-line relationship between the enterococcal index and the *E. coli* index is apparent when the results are plotted one against the other (Figure 2). A theoretical straight-line equation was calculated which would best fit the observed points. This was found to be $y = 2.2 + 0.14x$, where y is the enterococcal index and x is the *E. coli* index. (The slope of this theoretical equation is expressed by b in the generic formula $y = a + b\ x$.) To prove that an increase in one index is related with a statistically significant increase in the other, the b slope was compared with a slope of zero, which would indicate an insignificant increase. The test demonstrated that the b slope is significantly different than zero with a t value of 2.8.

Since a straight line can be plotted with accuracy which fits the observed data, it becomes apparent that there exists some definite relationship between the density of *E. coli* and enterococci. An increase in the *E. coli* count is followed generally by a predictable increase in the enterococci count. A correlation coefficient was found to be positive, with a value of $r = +0.7$. This indicates that the relationship is direct and that an increase of one is coupled closely with an increase of the other.

A ratio of the magnitude of densities of *E. coli* and enterococci was determined by using the arithmetic median of the 109 samples. *E. coli* was isolated in a ratio of 63.1 to enterococci. This ratio is logical, as there are fewer enterococcal bacteria in raw, fresh sewage as compared to *E. coli* (1), and it has not been demonstrated that enterococci have the ability to multiply naturally after leaving the intestinal tract, as has been demonstrated with *E. coli* (10).

If, in further investigation, the enterococci index is found to be a more reliable index of recent pollution than the *E. coli* index, the ratio of magnitude of density of *E. coli* to enterococci of 63 : 1 suggests the use of larger portions of samples for enterococcal determinations to compensate for the naturally lower density of enterococci.

The enterococci test as employed in this study has disadvantages when compared to the *E. coli* test. The de-

termination of positive presumptive tests is not clearcut in many cases and additional investigations are being conducted for clarification. For a presumptive tube to be classified as positive, the production of acid (yellow color) and turbidity must be noted. Not all positive presumptive tests show the same degree of acidity; hence, there is a variation in the color of the indicator. This makes it difficult to determine which tubes should be analyzed by the confirmatory test. If necessary, all doubtful positive tubes of the presumptive test can be checked by the confirmatory test, but this increases the amount of work and the cost. One of the difficulties of interpretation may be due to interference by other organisms. *Bacillus subtilis* has been described as being capable of interfering in the presumptive test (11).

Another difficulty of the enterococcus test of Winter and Sandholzer (3) is the reading of slides made from the

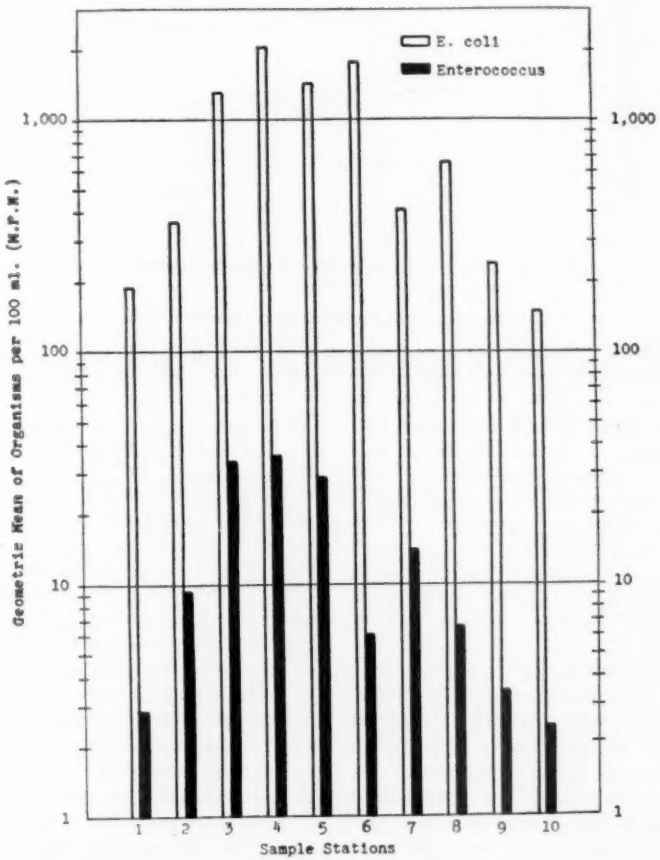

FIGURE 1.—Relationship of the geometric mean of the *E. coli* density to the enterococcus density for samples collected from New Haven, Conn., harbor (Dec., 1949–Feb., 1950).

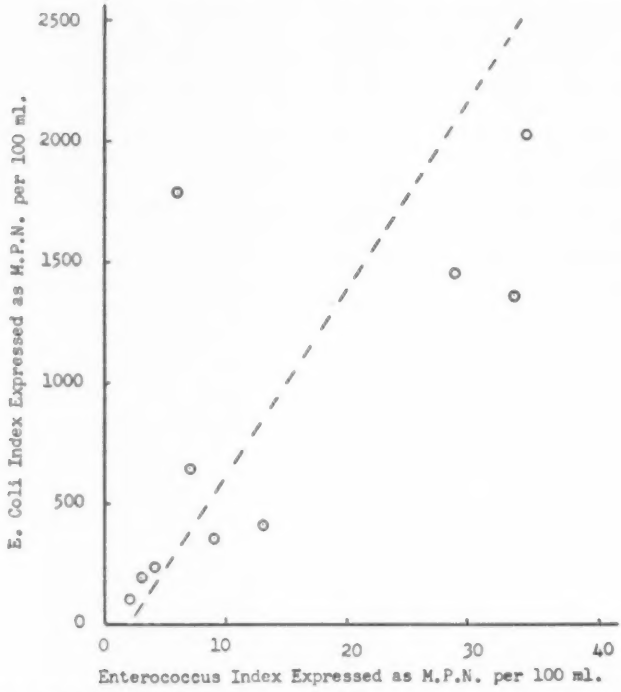

FIGURE 2.—Relationship of geometric means of observed *E. coli* index to observed enterococcus index for each sampling station and the theoretical line $y = 2.2 + 0.014x$.

growth in the slant-broth tubes and Gram-stained. By definition, the enterococci are large, Gram-positive, ovoid, pleomorphic cocci, appearing in singles, pairs, or short chains. This definition alone makes them atypical of other streptococci, but after growth in a penicillin medium their morphological characteristics can be further changed (12), giving occasion for speculation on the part of the technician. The confirmatory slant-broth medium is time-consuming to prepare and also presents the possibility of contamination after sterilization, because the broth must be poured aseptically. It is true, however, that the penicillin contained in the broth may inhibit many contaminating organisms.

One advantage of the enterococci test is that it can be completed in 48 hr. as compared to 72 to 90 hr. for an *E. coli* analysis.

The presence of enterococci indicates fecal pollution if it is assumed that an *E. coli* index measures pollution. The correlation coefficient of + 0.7 and the inability to isolate enterococci from any sample without *E. coli* substantiates this fact.

Although the presence of enterococci did indicate pollution of a sample, the absence or inability to isolate enterococci from a sample did not establish non-pollution using the present criterion of pollution measured by the *E. coli* density. This was demonstrated by 20 samples showing no enterococci in the dilutions used for this study, but substantial *E. coli* den-

sities. As previously stated, this occurrence might have been avoided by using larger portions of sample.

Conclusions

From the limitations of this study, the following conclusions are reached:

1. A positive correlation of + 0.7 exists between the confirmed *E. coli* test of "Standard Methods" (13) and the enterococcus test of Winter and Sandholzer for samples of water collected from a body of sewage polluted salt water during the winter months, and a high *E. coli* index will predict, generally, a correspondingly high enterococcus index.
2. Based upon the median value of all samples collected and analyzed in this study the density of *E. coli* will be approximately 63 times that of enterococcus.
3. More skill is required by laboratory personnel in performing the enterococcus test of Winter and Sandholzer than the accepted confirmed test for *E. coli*.
4. The enterococcus test of Winter and Sandholzer can be completed in a shorter period of time than that required for a completed test for *E. coli*.

Summary

The coliform test for water pollution is not ideal, although well established in the field of water bacteriology. The argument over the sanitary significance of certain species of coliforms has subsided somewhat in the past few years. With the exception of a few investigators, research in methods for the improvement of water analysis has diminished because of the general acceptance of the coliform and *E. coli* test.

The isolation from water of the enterococcus group of organisms has been recognized as a possibility for determining fecal pollution of water. Recently a method for enterococci isolation has been devised by Winter and Sandholzer. The study described herein was an attempt to compare pollution of a body of salt water measured by the results of a standard confirmed test for *E. coli* with the enterococcus test of Winter and Sandholzer, a test which had been used by the United States Public Health Service in the sanitary examination of fresh water.

Samples were collected weekly for 11 weeks, during the winter months, from 10 sample stations along the New Haven, Conn. harbor, a body of salt water. The samples were analyzed bacteriologically for the presence of *E. coli* and organisms of the enterococcus group.

The study indicated that enterococcal densities followed the pattern of *E. coli* indices; a correlation coefficient was calculated for the relationship between the two sets of indices and found to be + 0.7. The enterococcus densities, however, were of lesser magnitude than the *E. coli* densities, being isolated in an approximate ratio of 1 : 63 with *E. coli*.

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WATER QUALITY STANDARDS PROJECT

A project to consolidate all available information on water quality standards as an aid to water pollution control agencies is under way at the California Institute of Technology. The work, involving a critical evaluation of thousands of references, is being done under contract with the California State Water Pollution Control Board. J. E. McKee, associate professor of sanitary engineering, is directing the project for the Institute.

The survey, according to a spokesman for the Board, has a two-fold purpose: to make the data on water quality requirements for all beneficial water uses readily available to the state and nine regional boards, and to indicate where more research is needed.

The project is to include study and interpretation of:

1. Water quality standards or requirements recommended by the original investigators and researchers.

2. The range of water quality standards (upper and lower limits) which would be permissible for varying field conditions and beneficial water uses.

3. Instances where the standards recommended by the original investigators have been embodied in and applied through ordinances, legislation, and rules and regulations of governing bodies and water pollution control agencies.

4. Court rulings and decisions which have passed upon the reasonableness of water quality standards as established by public agencies.

5. Bibliography of reference material.

6. Findings, conclusions, and recommendations on water quality standards and on additional research necessary.

RELATION OF B.O.D. TO STREAM DEOXYGENATION * †

By Walter E. Williams

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For years, B.O.D. has been used as the measuring device in the analysis of streams. It is true that this test is complex in its action and often appears to produce erratic results. However, in the final analysis all B.O.D. tests are run in connection with either the future or the actual effect of the B.O.D. upon a stream. It follows that, because such a complex entity as a stream is being dealt with, only an equally complex method of analysis can yield corresponding results. A certain amount of inconsistency is to be expected because of the nature of this test; but, as has so often been pointed out, if sufficient data are procured to be treated statistically, valid results may be obtained. However, it must be remembered that statistical analysis is a useful tool and not a substitute for clear thinking. It cannot be denied that collecting sufficient data and studying the peculiarities in any case becomes a long and tedious job. This, however, appears to be the only intelligent method to follow.

Fundamental Concepts

Basic Law

The foundation upon which all B.O.D. computations are based is aptly stated by Phelps (1) as follows: "The rate of biochemical oxidation of organic matter is proportional to the remaining concentration of unoxidized substance, measured in terms of oxidizability." In other words, the rate of increase in organisms which utilize organic matter can be expected to be proportional to the concentration of the food supply available, and the oxygen demand caused by these bacteria should in turn be proportional to their rate of increase.

In the mathematical representation of the law, Phelps first expresses the law in differential form—

$$-\frac{dL}{dt} = K\,L$$

Integrating,

$$\log_e\left(\frac{L_t}{L}\right) = -\,K\,t$$

or

$$\frac{L_t}{L} = 10^{-kt} \qquad (1)$$

in which L is the initial oxidizability at zero time, or the ultimate demand; L_t is the oxidizability at time t; L_t/L is the oxidizable fraction at time t; K represents the velocity constant in natural logs; and k represents the velocity constant in common logs.

Velz (2) has graphically represented this formula using a logarithmic scale for the percentage of the remaining fraction, and regular coordinates for the time. This representation is shown in Figure 1. He has used this relation in stream analysis to indicate the percentages of the original pollution remaining at various flow times downstream.

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† From a thesis in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering at the University of Minnesota.

It will be noticed that Eq. 1 is in terms of the oxidizable fraction remaining, rather than the fraction oxidized at time t. To put this in more familiar terms, let X_t represent the B.O.D. or the amount oxidized at time t, or

$$L_t = L(10^{-kt})$$

But

$$L_t = L - X_t$$

therefore,

$$X_t = L - L(10^{-kt})$$

or

$$X_t = L(1 - 10^{-kt}) \qquad (2)$$

Eq. 2 is the practical formula used in the interpretation of the B.O.D. test. Plotting of this equation yields the well-known B.O.D. curve. Generally, results conform measurably well to this curve and the basic law; however, there are instances where oxygen demands do not vary in proportion to the concentration of the nutrients present. In the case of certain specific nutrients, addition of nutrients beyond an opitmum point may have a toxic effect, which results in less activity and lower oxygen demands. It may also be true that the symmetry of the curve is not exactly followed when carefully studied (3). However, in the case of a stream or normal sewage, where a multitude of organisms and nutrients are present, the over-all combination should level out variations and the curve should be followed well enough for all practical purposes.

Velocity Constant

The rate at which organic matter is decomposed in the deoxygenation process is mathematically measured by k, the velocity constant. The exact significance of this constant is not immediately apparent because of the development of the natural logarithm in the integration. Study will show that for any given k, and for any given unit of time, a constant fraction of the remaining oxidizable matter will be oxidized. For example, assuming $k =$ 0.10, during each day 20.4 per cent of the residual at the beginning of the day will be oxidized. This holds true for any day of the test so long as the k-value remains at 0.10. Again referring to Figure 1, it is seen that the higher the velocity constant the faster the stabilization of the material proceeds.

The early work in this area was done by Phelps (4) in 1909, in which he determined that at 20° C, the velocity constant of Boston sewage was approximately 0.10. He later arrived at the same value for Washington sewage. Later work by Lederer (5) and Theriault (6) indicated some variation in the velocity constant, but agreed that 0.10 was a good average value for normal sewage. Theriault's study was made in 1927 and until recently there has been little further done along this line. It has become common practice to assume a velocity constant of 0.10 in B.O.D. computations. However, it has been pointed out in recent literature (7) (8) (9) (10) that this generally accepted value of 0.10 may be low. These articles indicate that a constant in the vicinity of 0.16 to 0.19 would probably be more correct. It is this question that provided the stimulus for the investigation reported herein.

It is well established that changes in temperature affect the rate of biochemical oxidation. Within ordinary limits the test reactions are speeded by increases in temperature. Detailed work on this subject by Streeter and Phelps (11), Gotaas (7), and Moore (12) can be found in the literature. The only point to be made here is that the magnitude of the velocity constant will vary with changes in temperature, and that estimates can be made of these variations with respect to temperature.

Nitrification

It is important to mention that up to this point only the carbonaceous de-

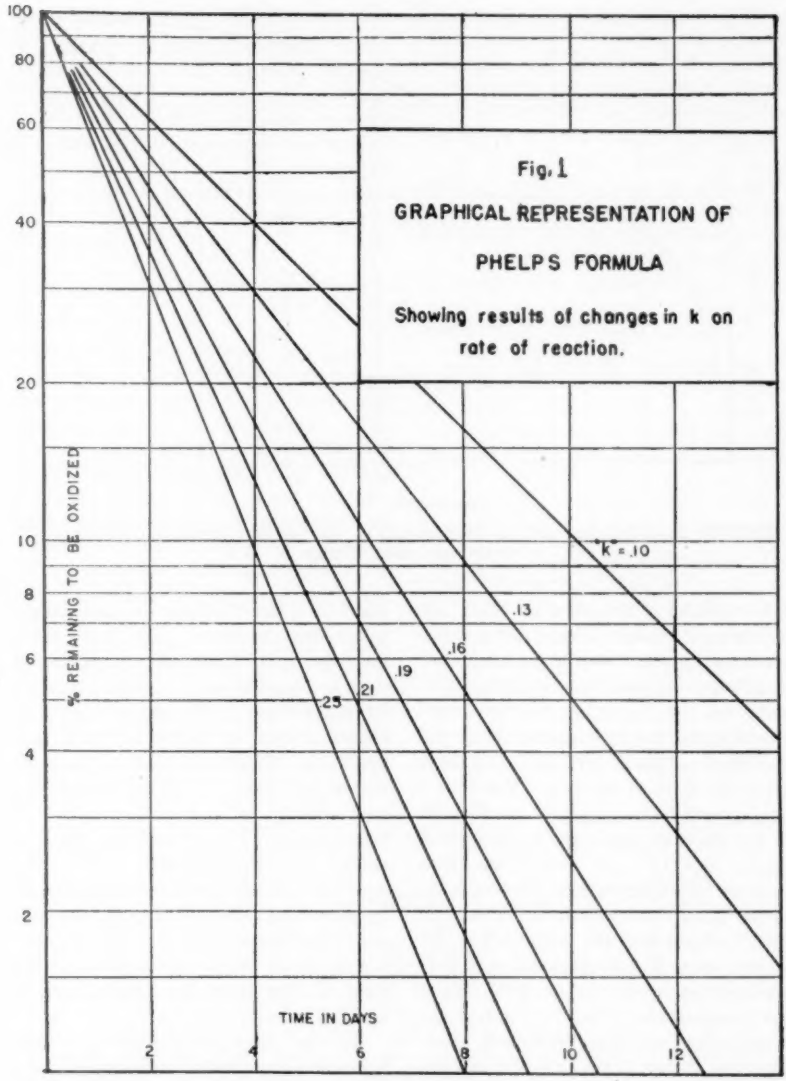


FIGURE 1.

mand upon the oxygen supply of the stream has been considered. There is in addition to the carbonaceous demand an apparently independent oxidation called nitrification, which results in a deviation from the curve, known as the second stage. Its influence can be seen on the curve in Figure 2, starting at about the thirteenth day. The second stage repre-

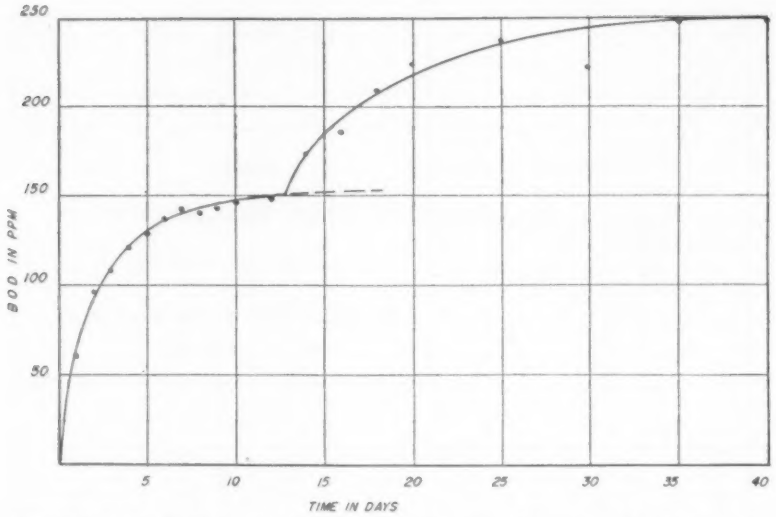


FIGURE 2.—Significant part of 100-day B.O.D. test on Minneapolis-St. Paul sewage treatment plant effluent.

sents a series of reactions in which ammonia and simple amino compounds are oxidized, first to nitrite, and then to nitrate. Generally, nitrifying bacteria do not assert themselves until almost all of the carbonaceous material has been oxidized, or about 10 days after the start of the test. There does not appear to be any real uniformity in the time at which the second stage begins in different situations, with authors reporting nitrification as early as the third day. Studies by Ruchhoft (10) indicate that the beginning of the second stage is not clean cut and that nitrification occurs to a small extent not recognizable by plotting before the second stage visibly asserts itself. Usually, the 5-day B.O.D. is not significantly affected by this phenomenon, but this possibility should not be overlooked.

Other Influencing Factors

A lag period will materially affect the computation of the velocity constant and the ultimate demand unless taken into account. The lag period refers to cases in which the oxidation does not proceed at a constant velocity from the start of the experiment, but rather starts at a low velocity and gradually builds up to a constant as shown in Figure 3. A lag results due to inactivity of the biological life in the sample. This inactivity may be caused by chlorination or, as in the case of chemical and biological wastes, by combinations of highly caustic and acid discharges. Correction for the lag is simply made by subtracting the time the lag consumes from the time normally used.

On the other hand, there is a less frequent so-called "immediate" demand, in which oxygen is consumed immediately. This is most likely a chemical demand and may occur if the sample is in an anaerobic or septic condition. To correct for this, time is added to the test. This is also shown in Figure 3.

Scope of Investigation

The scope of this study was to investigate the velocity constant of the Minneapolis-St. Paul treatment plant effluent and its effect upon the velocity constant of the Mississippi River, into which it discharges. An attempt to evaluate the significance of the velocity constant in stream analysis was also made.

Preliminary Investigation

100-Day B.O.D.

Before actually starting the investigation some preliminary studies were made to determine the best procedure to use in attacking the problem. The first of these was the consideration of a 100-day B.O.D. test run on the Minneapolis-St. Paul plant effluent. The results of this test are shown in Figure 2, in which only the first 40 days are shown, as no appreciable additional demand was exerted after that time.

The information to be gleaned from this test concerns the characteristics of the curve. It will be noticed that neither a significant lag period nor any immediate demand is evident. This fact was confirmed by some tests made during the first 8 hr. of incubation on other samples of the plant effluent. Thus, the computation of the velocity constant was not complicated by either of these factors. The other important feature to be noted is that the second stage was not visibly significant until about 12 or 13 days have elapsed. This would indicate that the tests on the first stage could be run for any period up to 10 days without nitrification appreciably affecting the results.

Selection of Procedure

There are two alternatives in the selection of a procedure in experimenting with the velocity constant. First, a large number of different daily portions can be tested for a small number of scattered days. This will permit use of the Thomas slope method of computation, and will give a small number of reliable daily k values. The second procedure would be to use only two different daily portions of a sample and to take samples every day over a long period of time.

The second alternative was chosen for several reasons. First, sampling errors are minimized, both from a purely mechanical standpoint and in

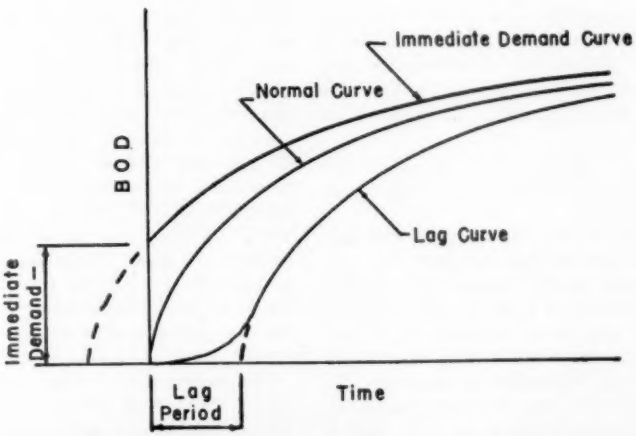


FIGURE 3.—Effect of immediate demand and lag period.

view of possible daily variations of the sewage itself. This selection also makes the procedure easier, as only one additional day need be run besides the 5-day B.O.D. used as part of the plant control in any case. Although any single constant found by this method will be less accurate, the average value found from a large number of samples will probably be more representative than if a few singularly more precise results were used. In addition to the 5-day B.O.D., a 3-day B.O.D. test was used because it would be least likely to be affected by a slight lag, immediate demand, or nitrification; and it would not create excessive demands on the incubator capacity.

Method of Computing Velocity Constant

The velocity of decomposition of a sample can be computed if three points on the B.O.D. curve are known. The points used in this investigation were zero time, or the actual start of the reaction at a constant velocity, and the 3-day and 5-day B.O.D. Inspection of Eq. 2 shows that a single B.O.D. test will have two unknowns, the ultimate demand, L, and the velocity constant, k. The time, t, and the B.O.D. for the time, X_t, will be known. However, if a second time interval is taken on the sample, the ultimate demand can be eliminated. Because the ultimate demand is the same in both cases, the two may be equated as follows:

$$L = \frac{X_{3\text{ days}}}{(1 - 10^{-3k})} = \frac{X_{5\text{ days}}}{(1 - 10^{-5k})}$$

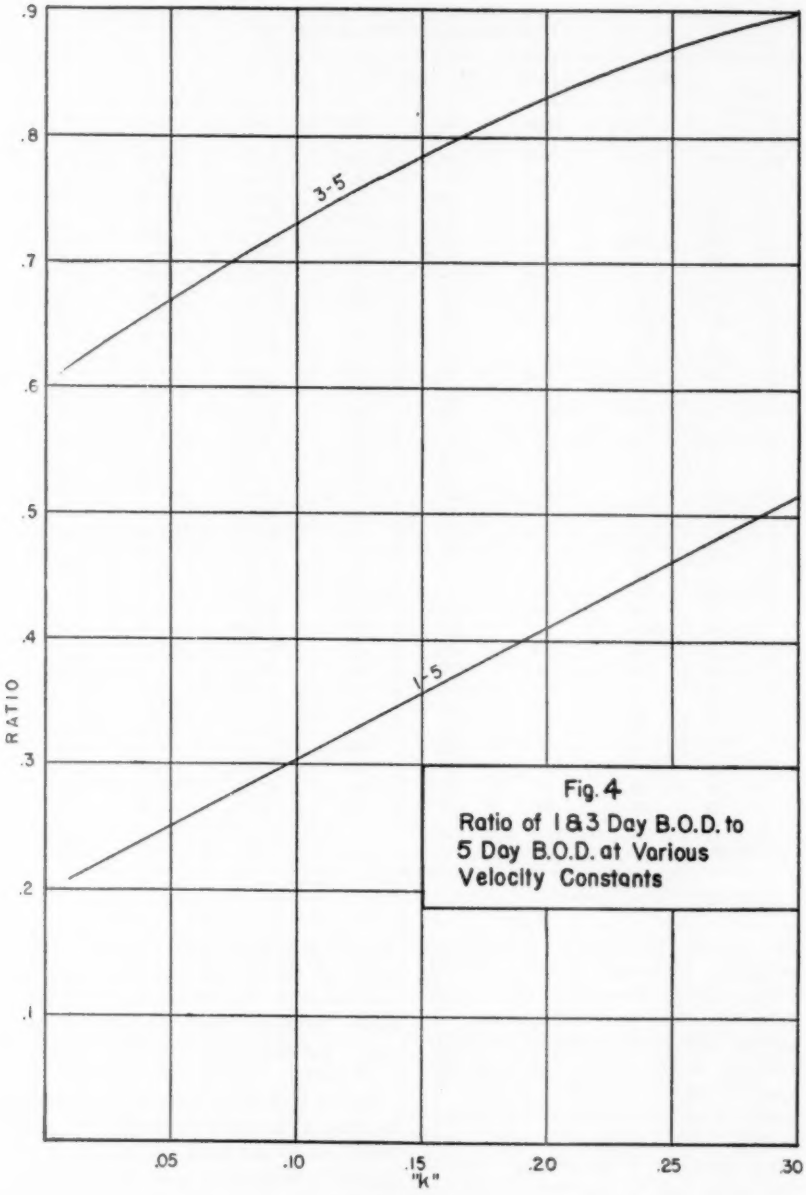
This, of course, leaves only one unknown—the velocity constant, k.

Because of the exponential position of k, solution is most readily done by a trial and error method, which becomes a tedious job if there are a large number of constants to compute. To simplify the job, the percentages of the ultimate satisfied in 1, 3, and 5 days were first computed for velocity constants from 0.050 to 0.300 at intervals of 0.005. The 1-day values were computed for use in the river investigation discussed later. Inspection of these results revealed that for any given k the percentage of the ultimate satisfied at the end of 3 days would be a fixed proportion of the amount satisfied in 5 days, regardless of the magnitude of the ultimate. It stands to reason that the ratio of the percentage of the ultimate satisfied in 3 days as against 5 days will be the same as the ratio of the 3-day to the 5-day B.O.D. Therefore, the proportions of the amounts satisfied in 1 as against 5 days and 3 as against 5 days were computed for the k values selected. These ratios (Figure 4) permit very rapid calculation of the velocity constant for these time intervals.

Investigation of Minneapolis-St. Paul Effluent

The Minneapolis-St. Paul plant is a primary treatment plant with flow through the sedimentation tanks divided into east and west sections. These sections are identical in size and number of tanks and both are usually in operation. A composite of each section was used for daily samples in this investigation. Two dilutions of both effluents were tested for 3 and 5 days and the daily values of k for the east and west effluent were computed (Table I). It will be noticed that for any single day the k of the east effluent does not necessarily agree with the k of the west effluent. This disagreement for a single day is to be expected when the B.O.D. test is used in this way. However, averages of a large number of days should be expected to agree closely. These tests were run for 34 days and the average values for the east and west effluents agreed very closely, confirming this theory.

The averages of the two daily constants were then found (Table I). When plotted on probability paper (Figure 5) the averages appear to fit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"K"
Fig. 4
Ratio of 1 & 3 Day B.O.D. to
5 Day B.O.D. at Various
Velocity Constants

FIGURE 4.

TABLE I.—Values of k for Effluent from East and West Sedimentation Tanks of Minneapolis–St. Paul Plant

Date (1950)		3-Day B.O.D. (p.p.m.)[1]		5-Day B.O.D. (p.p.m.)[1]		Value of k		
		East	West	East	West	East	West	Av.
March	23	84.0	94.5	96.5	105.5	0.250	0.290	0.270
	24	79.4	84.5	100.5	101.0	0.155	0.205	0.180
	25	69.5	72.5	89.0	93.5	0.145	0.140	0.142
	26	61.5	69.5	84.0	89.0	0.105	0.145	0.125
	27	28.5	33.0	38.5	43.0	0.110	0.130	0.120
	28	76.5	78.0	93.0	95.5	0.190	0.185	0.188
	29	118.0	127.0	139	150	0.220	0.220	0.220
	30	120.0	122.0	146	145	0.190	0.210	0.200
	31	123.0	128.0	143	145	0.230	0.265	0.247
April	1	115	113	135	143	0.220	0.155	0.187
	2	103	114	125	142	0.190	0.165	0.177
	3	171.0	80.0	87	100	0.180	0.165	0.172
	4	44	151	162	178	0.275	0.220	0.247
	5	132	133	156	154	0.215	0.240	0.227
	6	117	110	130	133	0.295	0.195	0.245
	7	117	107	144	129	0.180	0.200	0.190
	8	111	104	130	121	0.225	0.235	0.230
May	5	115	105	145	130	0.160	0.170	0.165
	6	63	55	76	65	0.200	0.210	0.205
	7	76	63	91	81	0.200	0.145	0.173
	8	67	48	79	61	0.210	0.155	0.182
June	3	124	118	149	142	0.200	0.200	0.200
July	13	87	82	114	98	0.130	0.195	0.162
	14	116	100	129	117	0.285	0.225	0.255
	15	104	95	121	117	0.230	0.185	0.207
	16	78	69	102	87	0.130	0.155	0.142
	21	90	84	117	108	0.135	0.135	0.135
	22	76	80	98	92	0.140	0.245	0.192
	23	48	46	62	61	0.135	0.125	0.130
	24	49	41	59	57	0.195	0.090	0.142
	25	81	82	102	100	0.155	0.175	0.165
	26	105	119	115	138	0.305	0.240	0.272
	27	90	97	101	190	0.275	0.275	0.275
	28	81	81	97	93	0.205	0.250	0.227
Average		—	—	—	—	—	—	0.194

[1] Average of two dilutions.

the normal probability distribution very well. This shows a mean of 0.192, which agrees favorably with other data found in recent literature. It will be noticed that none of the daily averages is as low as the commonly accepted value of 0.10, and that 80 per cent of the k values can be expected to be greater than 0.15. Figure 5 also shows that 50 per cent of the values can be expected to fall between 0.160 and 0.225. It is evident that these variations cannot be attributed to the characteristics of the B.O.D. test alone and that the value of k of the sewage is also varying. An attempt was made to correlate these variations with the days of the week, but this met with little success.

Primary interest is centered on value of k of the plant effluent in connection with the stream analysis, and these results show the common assumption of 0.10 to be in error with respect to this effluent. Before going on to the stream analysis, however, some sidelights of these results may well be con-

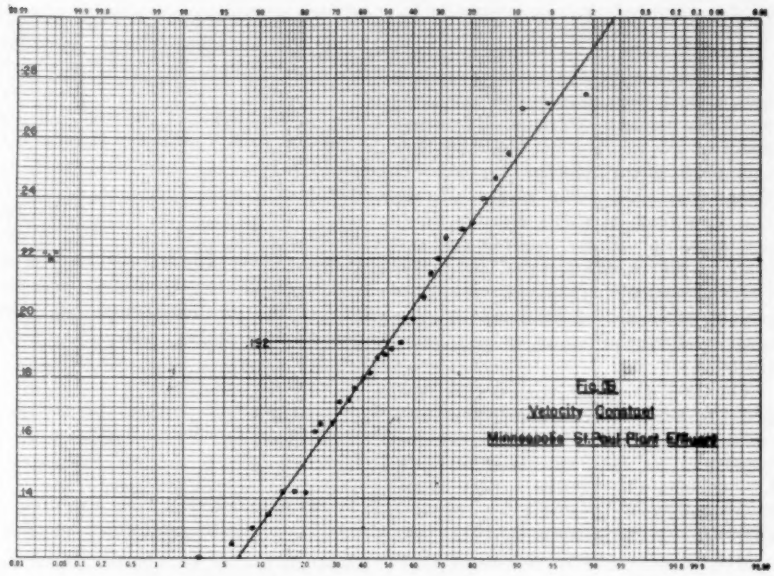

FIGURE 5.—Probability plot of k values for Minneapolis-St. Paul plant effluent.

sidered. The question arises as to whether or not the average k for normal sewage has increased since the early work was done. It seems likely that with the advent of so many modern conveniences this may be the case. It should be remembered, also, that this experiment was made on plant effluent and not on raw sewage as in earlier tests. To clear up this point as to whether or not the sedimentation process had any effect on values of k, a series of tests on the raw sewage were run.

TABLE II.—Values of k for Raw Sewage and Final Effluent at Minneapolis–St. Paul Plant

Date (1950)	3-Day B.O.D. (p.p.m.)[1]			5-Day B.O.D. (p.p.m.)[1]			Values of k		
	Raw	East	West	Raw	East	West	Raw	East	West
July 13	145	87	82	180	114	98	0.175	0.130	0.195
14	161	116	100	205	129	117	0.155	0.285	0.225
15	158	104	95	195	121	117	0.175	0.230	0.185
16	141	78	69	180	102	87	0.155	0.130	0.155
21	133	90	84	174	117	108	0.130	0.135	0.135
22	110	76	80	142	98	92	0.140	0.140	0.245
23	95	48	46	124	62	61	0.135	0.135	0.125
24	70	49	41	88	59	57	0.165	0.195	0.090
25	145	81	82	190	102	100	0.130	0.155	0.175
26	169	105	119	201	115	138	0.205	0.305	0.240
27	148	90	97	176	101	110	0.210	0.275	0.275
28	127	81	81	158	97	93	0.170	0.205	0.250
Average	—	—	—	—	—	—	0.161	0.193	0.191

[1] Average of two dilutions.

Comparison of k *for Raw Sewage* vs. *Effluent*

In addition to the tests described above, tests were run on the raw sewage for a period of 10 days. The average k of the raw sewage was 0.161 for this period; the average for the effluent was 0.192. The results (Table II) show that for this series the average k of the effluent corresponds exactly to that found for the longer period previously discussed, enabling placing of some confidence in the raw sewage results obtained in this relatively short time.

The fact that the raw sewage appears to have a k value somewhat less than that for the effluent is very interesting. It, however, still remains higher than 0.10. There appear to be two possible explanations for this occurrence. It is possible that the less oxidizable materials settle out, or that the size of the particles may be an important influence, or both. Large particles will have comparatively less surface area for the aerobic bacteria to reach or affix themselves to, thus making the rate of the reaction slower where they are present. The effluent, which contains the smaller, less compact particles, may be oxidized more rapidly.

The fact that the k values of the raw sewage and final effluent of a plant may be different has an interesting effect upon the calculation of plant reductions. In the method presently used the 5-day B.O.D. of the effluent is subtracted from that of the raw sewage and then divided by the B.O.D. of the raw sewage. Actually, removals should be based upon the ultimate demands of each, but if the k of each is the same the 5-day and the ultimate demands of each are in the same proportion and the conversion to the ultimate is unnecessary. However, when k is not the same in both cases this simplification can not be applied. Take the case of the Minneapolis-St. Paul plant, using average values of 195 p.p.m. for the raw sewage and 115 p.p.m. for the plant effluent. Computing in the usual way yields a 41 per cent removal of the B.O.D. However, if one calculates in the light of the k values found in these tests a difference in the reduction will be noticed.

For example, at a k of 0.161 for the raw sewage, 84.4 per cent of the ultimate demand is satisfied in 5 days; at a k of 0.192 for the effluent, 89.0 per cent of the ultimate demand will be satisfied in 5 days. Thus, the reduction is

$$100 - \frac{\frac{115}{0.890}}{\frac{195}{0.844}} \times 100$$

= 44 per cent reduction, based on ultimate oxygen demand.

Although the increase in the actual reduction is not large in this instance, it seems likely that in the case of industrial wastes, and possibly oxidizing filter plants, the discrepancy may be considerable more. An investigation of this relation is now being carried on.

If the k of raw sewage is greater than 0.10, other values based upon this value, such as the population equivalent, may well be reinvestigated by the field to bring them up to date with apparent changes in normal sewage.

Investigation of River k Values

The study also involved the investigation of the value of k of the river water, both before and after mixing with the plant effluent. River data compiled by the Minneapolis-St. Paul Sanitary District since 1928, first for determining the degree of treatment required and now as part of the plant control, were especially valuable for this purpose. The district regularly samples a 90-mi. stretch of the Mississippi River. The analytical information collected includes physical,

chemical, biological, and bacteriological data. However, of special interest here is the fact that 1-, 5-, and 10-day B.O.D.'s have been recorded at most of the sampling stations.

For the purpose of this investigation only a section of the sampled length was used. Only the critical section of the stream just above and for a distance of 20 mi. below the plant outfall was studied. Carrying the investigation farther downstream would introduce two possible sources of uncertainty in oxygen balance computations. As shown in Figure 6, these would be the acceleration of the reaeration process caused by the water passing Hastings Dam and the junction with the St. Croix river just below the dam. For this stretch of the river, data are most complete at mile point 13.8, the Robert St. Bridge in St. Paul, above the treatment plant effluent; at station 18.0, below the Minneapolis-St. Paul effluent, but above the South St. Paul plant ef-

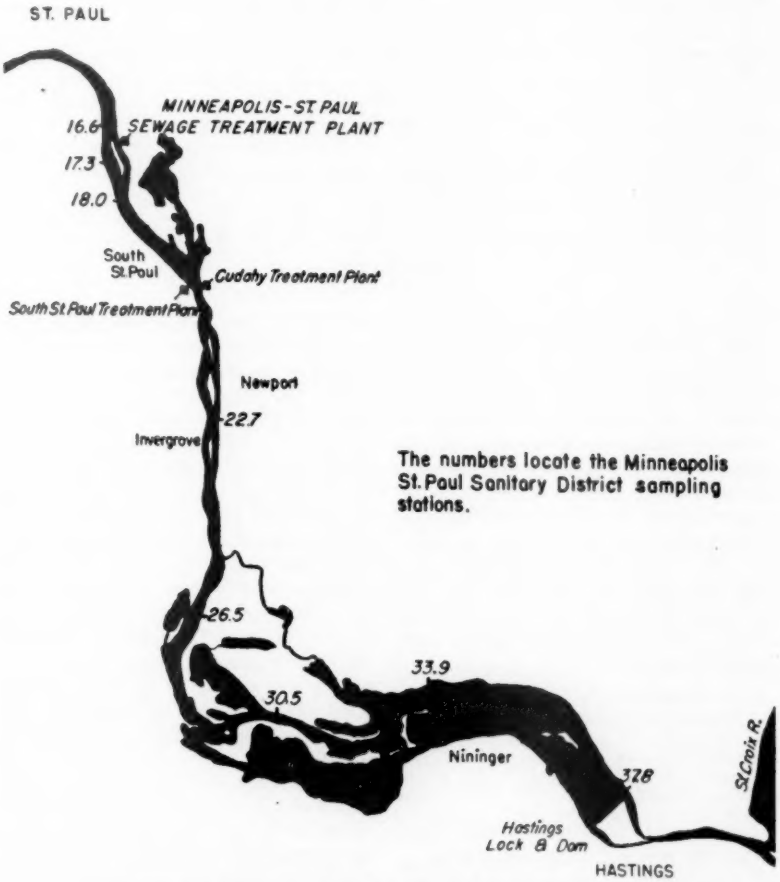

FIGURE 6.—Mississippi River from St. Paul to Hastings, Minn.

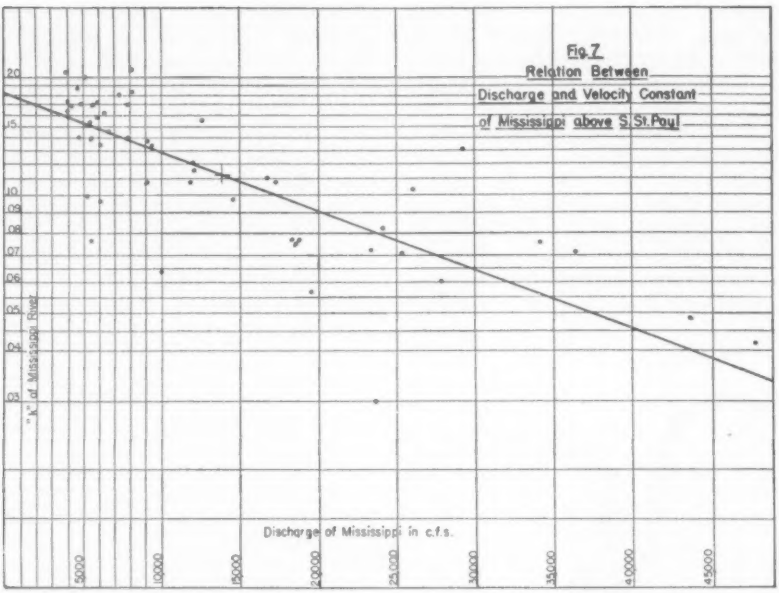

FIGURE 7.

fluent; at station 22.7, Intergrove, which is below all sources of known pollution; and at Grey Cloud Landing, mile point 30.5, which is well below the discharge of pollution.

The procedure in each case was to compute the k value between the 1-day and 5-day B.O.D. for each daily sample given for the years 1944 to 1948, inclusive. These daily values were then averaged by months to arrange the data into uniform time intervals so an over-all average could be taken. The over-all averages for the four stations were:

Sampling Point	Av. k
13.8 Robert St. Bridge, above Mpls.–St. P. plant	0.086
18.0 Below Mpls.–St. Paul plant	0.121
22.7 Below South St. Paul plant	0.119
30.5 Grey Cloud Landing	0.105

It appears that changes in the value of k will occur during the cycle of self-purification. The river enters the stretch at a low k value, indicating that little highly oxidizable material is present and that the nitrification stage is probably predominant. As the river passes the plant the highly oxidizable material from the plant increases the value of k of the mixture. As the river moves on downstream the value of k appears to decrease continually as more and more of the highly oxidizable material becomes stabilized and no longer exerts its effect. It is interesting to note that the average k in the pollutional zone is very close to the 0.10 value found by earlier workers for river water and sewage. However, it does not appear to diminish to 0.10 until after the critical point in the stream is reached, which, of course, is significant.

In working out the various daily values of k it was noticed that the high values of k were found in periods of low flows, and *vice versa*. This was especially noticeable at station 18.0, which is about a mile below the Min-

neapolis-St. Paul effluent. This would seem logical, as the effluent's high k would have a more dominant effect at lower flows. The next step was to try to find the strength of the relation between the river k and the dilution or flow. The data plotted up very favorably on semi-log coordinates with k as the ordinate and the flow as the abscissa (Figure 7). The coefficient of correlation was computed and found to be 0.88, which indicates a high relationship. It is especially interesting to note that when the mixture approaches a value around 200 cu. ft. per sec., where it would consist almost entirely of plant effluent, $k = 0.18$. This agrees very well with the value of 0.192 found by actually testing the effluent.

These results support the theory that upon mixing the plant effluent and the river will continue to be oxidized at the same rate as before mixing, with the velocity of oxidation of the mixture simply representing the summation of the deoxygenation of the two components. This theory was further investigated in the laboratory by determining the k of a river-water sample and a sample of the plant effluent, and simultaneously finding the k of known mixtures of the two. Having these results, the next step was to find if B.O.D.'s of the mixture can be computed knowing only the B.O.D.'s of the two ingredients; or, in other words, does the B.O.D. of the mixture equal the sum of the B.O.D.'s of the two ingredients? The results of this comparison are shown below:

Mixture	3-Day B.O.D.		5-Day B.O.D.	
	Calculated	Observed	Calculated	Observed
1 in 30	5.07	5.19	6.29	6.32
1 in 40	4.22	4.30	5.28	5.45

The calculated and observed values appear to agree rather well, considering the accuracy of a single run.

It was concluded that calculation of the B.O.D. of a mixture for any time can be reasonably well accomplished knowing only the demands, the k values, and the proportions of the contents. In other words, it does not seem likely, in the case of a stream, that there is any sizeable change in the rate of decomposition of a single particle due to mixing with other particles decomposing at a different rate.

Significance of k *in Oxygen Balance*

One of the purposes of this study was to evaluate the significance of errors caused by assuming a velocity constant of 0.10 in stream analysis, rather than determining the actual k values for the various sources of pollution. In this respect, a complete oxygen balance for the stream section was made, in which computations using a value of $k = 0.10$ were compared to those using the actual values of k. In this particular case the error caused by assuming $k = 0.10$ was not large, amounting to about 0.5 p.p.m. oxygen demand in the critical stretch of the river. It is sufficiently large to be worthy of consideration if it is at all possible to determine the approximate values of k for the various sources of pollution, especially in cases of low dilution.

Discussion and Summary

In the stretch of the Mississippi River considered, it was seen that the value of k of the mixed sewage and river water was reasonably close to 0.10. Thus, it is not surprising that computations in the stream analysis using actual velocity constants were close to those found using $k = 0.10$. It must be remembered that a normal sewage and a particular stream has been dealt with here. For a similar situation, it seems reasonable to state that the use of $k = 0.10$ in stream analysis may not introduce a large error. It is clear that in the case of peculiar situations, especially where

large amounts of industrial wastes and low stream flows are encountered, the assumption of $k = 0.10$ would be dangerous practice. The reason for this is that the value of k of a mixture appears to have a more direct relationship to the proportion of the ingredients. Thus, when a strong waste with a very high or very low k value flows into a stream with a low discharge the mixture will tend to decompose at a rate approaching that of the waste alone. Errors in such a case might easily reach a magnitude of considerable importance.

The previous discussion has dealt only with the critical period, which includes times of passage up to the order of 2 days. Consideration is now given the entire cycle with reference to the k value. Assuming that both are calculated from the same 5-day B.O.D.'s, a high k value will exercise a greater demand in the earlier stages than will a lower one. By the time 5 days have elapsed, either computation will, of course, result in the same demand, simply because all other points are based on this value. After 5 days of flow the demand computed with the low value of k will begin to exert progressively greater demand than if computed with a higher value of k. This is simply because the ultimate demand based on the same 5-day B.O.D. for a high value of k will be less, as a greater proportion of the ultimate would be oxidized at this time. In other words, for the same 5-day B.O.D. a high value of k exerts less ultimate demand, but this demand is concentrated in the first few days. The low value of k will, of course, exert a greater over-all demand, but this demand will be less likely to cause a serious depletion over a short stretch of the stream.

In view of the complexity of each stream problem, it is strongly felt that each situation should be treated separately. Assumptions should not be made unless absolutely necessary. Comparison of B.O.D. results for any two situations in the form of standards should also be avoided. If comparisons are made, the characteristics, such as lags, etc., for each must be known and, if possible, the comparisons made on the basis of the ultimate demands as computed using the respective values of k. Comparisons within the same plant for determining reductions should also be made in this way unless it is determined that the k value remains about the same throughout the plant.

Results showing the k value of the plant effluent to be 0.192 and of the raw sewage to be 0.162 supplement other indications in recent literature that the k value of normal sewage today is in this range.

Acknowledgments

The author wishes to express his appreciation to Professor George J. Schroepfer for his guidance and assistance and to thank the staff of the Minneapolis-St. Paul sewage treatment plant, especially Messrs. Kerwin Mick, Maurice Robins, and Loeman Hamilton, for their valuable assistance. All laboratory tests referred to in this paper were run by the plant laboratory staff. To those who assisted in this capacity, the author expresses his appreciation.

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VALUE OF CLEAN WATER IN WASHINGTON

In an exceedingly informative and highly readable new 47-page booklet directed to the average non-technical citizen, the Washington Pollution Control Commission has presented the basic water use program for the state, the effects of pollution on those uses, the economic evaluation of the state waters from the standpoint of fishing, shellfishing, irrigation, and recreation, and the pollution correction program as new being carried out and as contemplated for the future. The aim of the booklet is to acquaint the general public with its responsibilities in pollution abatement and prevention, as well as with the Commission's role in and facilities for carrying out the program.

To point out the potential loss in value through stream pollution in the state, the report cites the $102,353,000 annual wholesale value of the fishing industry. If the amount invested in plants and equipment, the operating expenses, and the salaries are considered, the annual value of the fishing industry comes to $308,212,000. These figures exclude the value of the large recreational fishery. In addition, the shellfish industry in 1949 had a wholesale value of almost $14,000,000, again exclusive of the sport fishery.

For the 670,000 acres currently irrigated in the state, the annual water value (at an average of $125 per acre) for crop production amounts to $84,000,000. Potentially, water is available for an additional 1,500,000 acres of land, or a potential annual crop value of $177,000,000 at the same unit acre value. However, pollution of water sources has placed serious limitations on this as well as other uses.

Indirect values from the clean streams program are visualized from a 1949 tourist survey conducted in the state. This survey showed that more than 2,000,000 visiting tourists spent $123,200,000 with an estimated $8,000,000 spent in recreational water activities.

The booklet concludes with a statement of the present and future correctional program, both municipal and industrial, and a complete listing of the status of individual municipal projects. Also given is an outline of how the individual reader can further the pollution control program through his own personal effort.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

IS YOUR PLANT INSURANCE ADEQUATE?

As a result of unusual accidents at two Illinois sewage treatment plants recently, there was considerable discussion of the plant insurance problem at the Annual Illinois Sewage Works Operators' Conference, held at Springfield, Ill., March 29–30, 1951. In particular, the water tank failure at the Urbana-Champaign plant (see THIS JOURNAL, **23**, 3, 310) brought up the question of kinds and amounts of insurance.

Among the many points brought out was the fact that normal fire or boiler insurance does not cover such an eventuality as a pressure tank failure unless heating devices are involved. Otherwise, the policy must have special clauses to cover that type of occurrence.

With the increased cost of constructing or replacing plant units and equipment, and the changing situation of plants making enlargements or changes in processes, it is extremely important to review the entire plant insurance program periodically with a reputable insurance representative to be sure that the types and amounts of coverage carried are adequate. A unit-by-unit and building-by-building revaluation from the insurance viewpoint of risk involved and types of possible damage will be invaluable in making decisions of this nature. In this connection, it is patently unthrifty to have blanket coverage on the entire plant at the rate applicable to the digester and its control house. An example of this type of coverage was given during the discussion mentioned by one superintendent, who pointed out that under a previous blanket policy on his plant he had been paying for fire insurance on his trickling filters at the same rate as on his buildings and digesters! Separate policies on the various units reduced his premium payments substantially.

Another item to be carefully checked is multiple coverage and co-insurance. To have several policies of the same type on a plant unit may introduce unnecessary cost. But to save a few dollars on premiums by reducing the coverage and becoming a partial co-insurer is to assume a risk that extremely few plants can weather in case of a disaster, even of minor proportions. A good example of each of these types of programs also was given during the discussion. In the first instance, a sanitary district board, as a matter of policy, parcelled out its insurance on the plant to all of the local agents; overlapping coverage resulted, with extra cost to the district. In the second case, a fire causing only $12,000 worth of damage left a district with a $6,000 repair bill by reason of having saved a nominal amount on a yearly premium through assuming a 50 per cent self-insurance risk.

The insurance program on your plant should be designed only after a thorough study—and then kept up to date by periodical comprehensive review conscientiously carried out. Have you reviewed your program lately? If not, do it now!

H. P. O.

OPERATION AND MAINTENANCE OF NEW YORK CITY SEWAGE TREATMENT PLANTS*

I. General Aspects and Costs

By Nathan I. Kass

Chief, Bur. of Sewage Disposal Operation, Dept. of Public Works, City of New York, N. Y.

Facilities and Organization

New York City's sewage treatment and disposal facilities during 1950 consisted of 13 sewage treatment plants; some 25 miles of interceptors, together with 86 regulators; and 3 self-propelled sludge vessels and 2 sludge barges.

The quantity of sewage treated in the three years preceding 1950 was approximately 450 m.g.d. However, in 1950 the conservation of water, imposed by the prolonged drought, considerably affected the quantity of sewage reaching the city's plants. Thus, in spite of some increase in the contributing population, the flow for the year was about 13 per cent less than during each of the previous three years, or 391 m.g.d. Of course, the proportion of sewage treated to total city flow remained about the same; namely, 41 per cent.

It is gratifying to report that the Owl's Head treatment plant (Figure 1), with an immediate flow of about 125 m.g.d., will go into operation during 1951; the Hunt's Point plant, which will treat approximately the same quantity of sewage, is expected to be placed in operation during 1952. In addition, the Rockaway plant, with a designed capacity of 15 m.g.d., may also go into service during this period. With these three new plants, the sewage treated will approximate 70 per cent of the city's total contribution.

Operation and maintenance of the city's sewage treatment and disposal facilities are under the jurisdiction of the Bureau of Sewage Disposal Operation. This is one of the three parts of the Division of Sewage Disposal, Department of Public Works, the other two being Design and Construction. The Bureau of Sewage Disposal Operation consists of five sections, as follows:

1. Treatment.
2. Repairs and Maintenance of Mechanical Equipment and Structures.
3. Repairs and Maintenance of Electrical Equipment.
4. Laboratories.
5. Procurement, Contracts, and Personnel.

In addition to the operation and maintenance of the treatment plants, the Bureau conducts the annual summer harbor pollution surveys, industrial waste investigations as required, and special studies.

Because of the complex nature of modern sewage treatment and the scope of the work carried on by this bureau, it is necessary for the guidance of the men engaged in the operation and maintenance of the plants to draw upon the services of a technical staff specially trained in sanitary, mechanical, and electrical engineering and of those well versed in the fields of chemical and biological sciences. The total number of technical and non-technical personnel employed in the bureau during 1950 was 555, consisting of 39 technical men; 459 skilled, semi-skilled, and unskilled workers; and 57 members of the sludge vessel crews.

Of the 1950 average daily flow received at the plants (391 m.g.d.), 290 m.g.d. were treated by the activated

* A symposium of four papers presented at a meeting of the Metropolitan Section, New York Sewage and Industrial Wastes Assn.; New York City; April 10, 1951.

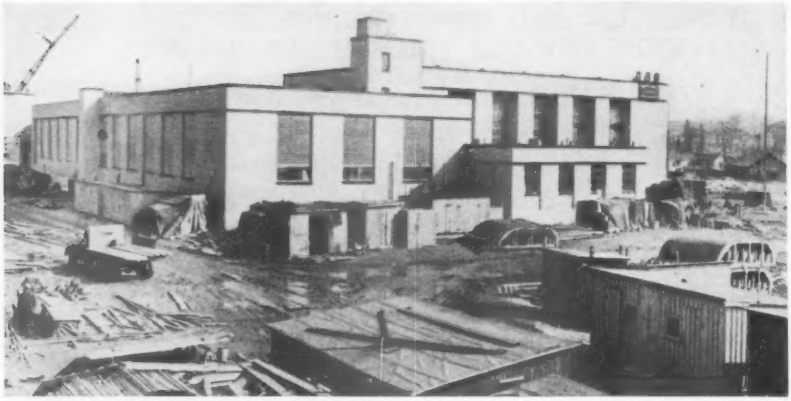


FIGURE 1.—Construction view of pump and blower house, Owl's Head sewage treatment plant.

sludge process, either conventional or modified. An additional 77 m.g.d. were treated by plain sedimentation, with 47 m.g.d. of this amount receiving chemical precipitation during the summer. The remaining 24 m.g.d. were subjected only to fine screening. Chlorination was provided on 126 m.g.d. for about 140 days during the bathing season.

Improvements in treatment at the different plants during 1950 resulted in an increase of about 12 per cent in solids removed as compared with 1949. The daily capture in 1950 was 327 dry tons.

The B.O.D. removals were also at a high level, the daily average of 164 tons being the greatest for the past decade.

By-Products

It may be of interest to note what has been done during 1950 with the by-products inherent to the processes comprising the treatment and disposal of sewage.

Important developments in the utilization of sewage sludge took place during 1950 and the few months preceding it. In October of 1950, the Commissioner of Parks made it publicly known through the daily press and the publication of a brochure entitled "Reclamation" that, based on the results of extensive investigations and experiments carried on by his consultant agronomists, the Park Department was accepting the consultants' recommendations for utilizing sewage sludge in making synthetic or artificial topsoil to be used in lieu of natural topsoil, which is badly needed and often difficult and costly to obtain. The demand for this material will become progressively greater in New York City when the now contemplated additional parks and other recreational areas get underway.

As to the quantity of materials for synthetic soil that can be produced in this city, there need not be any concern. Even with the present treatment plants, which are progressively increasing in number, about 70,000 tons of solids, on dry basis, are produced annually. It is regrettable, however, that at present only about 10,000 tons are deposited on sludge drying beds for future use, the remaining 60,000 tons being dumped at sea.

Nevertheless, some signs of greater appreciation of sewage sludge as a useful material for agricultural pur-

poses are in sight. In the fall of 1949, the Park Department let a contract for stockpiling about 10,000 cu. yd. of dried digested sludge, which was barged from the Coney Island plant and dried on improvised sand beds superimposed on sanitary landfill in Marine Park. This material was later distributed to city golf courses for use as a soil conditioner. Also, based on the experience gained at the Jamaica plant, the dry sludge accumulated at the 26th Ward plant for several years has been utilized under a landscaping contract for this plant, (Figure 2), where about 9,000 cu. yd. were consumed.

This trend toward a greater utilization of sewage sludge is gratifying. Perhaps the time is approaching when we will agree with Victor Hugo, who in lamenting the fact that Paris was constantly casting into the sea its human waste so valuable for agricultural purposes, ends his monologue in "Les Miserables" on the possible benefits to be derived from sewage sludge by saying, in part, ". . . It is the green grass . . . it is the perfumed hay, it is the gilded wheat, it is the bread on your table, it is the warm blood in your veins."

Meanwhile, however, the most utilized by-product produced at New York City's sewage treatment plants is sludge gas. During 1950, 423,000,000 cu. ft. of this gas was used at the Jamaica, Coney Island, Bowery Bay, and Tallmans Island plants, mainly as fuel for the 16 engines, which have a combined output of 10,500 hp. An equivalent of utility gas would cost about $375,000. The quantity of generated gas used during the year represents approximately 18,000,000 kw.-hr., or 77 per cent of all power requirements at the plants served by gas or dual-fuel engines (Figure 3).

The sale of sewage skimmings, which came into being in 1943 when the need for increased recovery of fats made itself felt because of the impact of World War II, is still being continued. The quantity sold annually is approximately 1,000 tons. Under 1951 conditions, the revenue from skimmings may amount to $35,000 for the year.

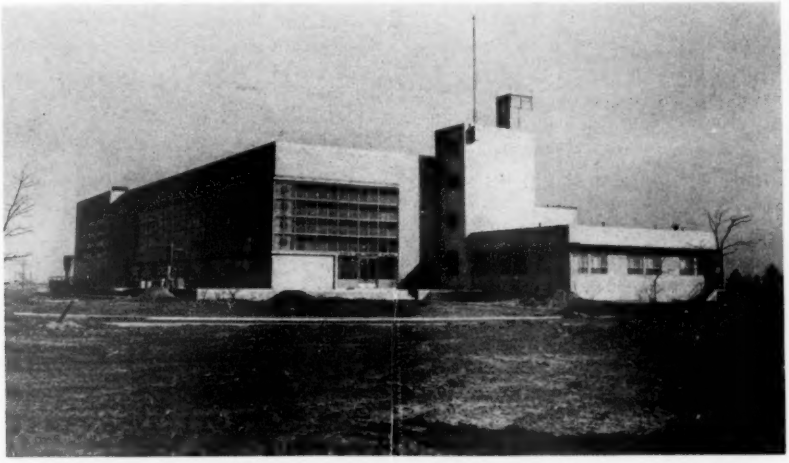


FIGURE 2.—Pump and blower house of 26th Ward sewage treatment plant. Note grading and landscaping operation, which used 9,000 cu. yd. of stored sludge.

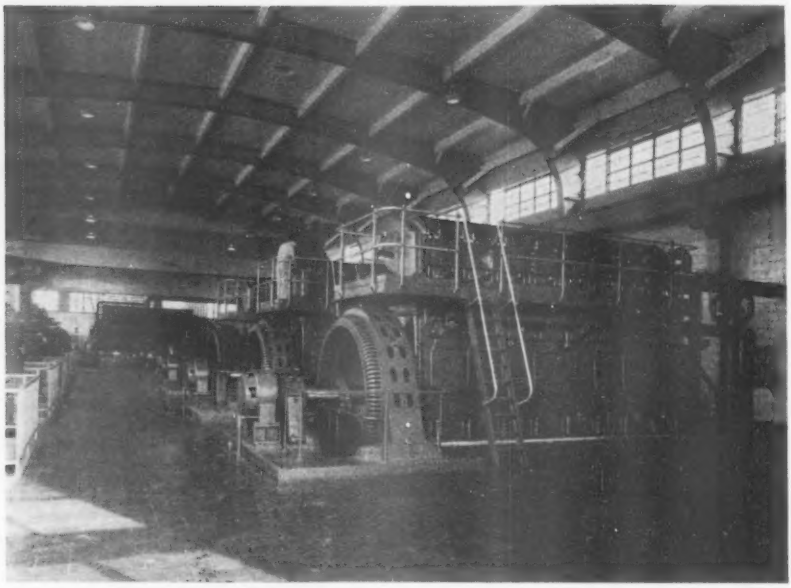


FIGURE 3.—Three 1,300-hp. duel-fuel engines at 26th Ward plant generate power from sludge gas. At rear, left, is 800-hp. gas engine direct-connected to blower.

FIGURE 4.—About 1,000 tons of grease skimmings from New York City plants are sold each year.

Cost of Treatment

Operating and maintenance costs of any utility vary, of course, from year to year. This is particularly true in the case of New York City's sewage treatment plants, where, in addition to the usual fluctuations in cost of labor and materials and the magnitude of annual repairs, there were also progressive increases in the sewage treatment facilities. Table I shows the expenditures during the years 1941 to 1950, inclusive, covering the operation and maintenance of the city's sewage treatment works, together with the pertinent activities of the bureau.

As would be expected, there is also a variation in the ratios of the elements of cost of operating and maintaining sewage treatment plants from year to year. Therefore, to get some general idea of what these ratios are, the average for the past 10 years was computed with the following results: Labor 53 per cent; power and light 23 per cent; and repairs, materials, and supplies 24 per cent.

The increase in the cost per million gallons of sewage treated in 1950 over that in 1949, as shown in Table I is due, of course, to the general rise in labor and material costs during 1950, coupled with the fact that there was a marked decrease in sewage flow because of water conservation.

Although it is customary to evaluate the economics of sewage purification by the cost per million gallons treated, it would seem that a better criterion for the effectiveness of sewage treatment would be the degree of purification attained, as measured by the removals and not by the quantity of sewage passing through the plant. With such a criterion (that is, on the basis of solids and B.O.D. removed) the comparison of cost of treatment favors 1950 over 1949, particularly in view of the marked increase in the cost of labor and material during the latter year. This comparison and the results of treatment previously noted bear witness to the fact that the operation and maintenance of the city's sewage plants during 1950 was rather satisfactory from the standpoint of economy and of the accomplished results.

TABLE I.—Cost of Treatment

Year	Sewage Treated (m.g.d.)	Solids Removed (dry tons)[1]	B.O.D. Removed (tons)[1]	Cost of Oper. and Maint. ($1,000)	Cost per m.g. Treated ($)	Cost per Dry Ton Removed ($)	Cost per Ton B.O.D. Removed ($)
1941[2]	375	80,000	50,000	1,362	10.13	17.12	27.24
1942[3]	367	92,000	55,000	1,398	10.62	15.26	25.42
1943[4]	401	78,000	57,000	1,498	10.23	19.12	26.28
1944[5]	415	104,000	57,000	1,835	12.09	17.50	32.19
1945	414	108,000	52,000	1,884	12.48	16.51	36.23
1946	436	107,000	58,000	2,110	13.27	19.66	36.38
1947	450	113,000	59,000	2,599	15.85	22.94	44.05
1948	446	113,000	49,000	2,695	16.50	23.72	55.00
1949	452	107,000	49,000	2,925	17.71	27.37	59.69
1950	391	119,000	60,000	3,217	22.55	26.94	53.61

[1] To nearest thousand.

[2] Plants in operation: Coney Island, Wards Island, Tallmans Island, and Bowery Bay primary treatment.

[3] Bowery Bay secondary treatment and City-Hart Island added.

[4] Jamaica secondary treatment *vs.* fine screens added.

[5] 26th Ward primary treatment *vs.* fine screens added.

II. Sewage Treatment Control

By Wilbur N. Torpey and A. H. Chasick

Engineer and Assistant Engineer of Sewage Treatment, Bur. of Sewage Disposal Operation, Dept. of Public Works, City of New York, N. Y.

The Sewage Treatment Section of the Bureau of Sewage Disposal Operation is responsible for preparing and issuing instructions to plant superintendants for the procedures to be followed in the various treatment processes. In the performance of their duties, the sanitary engineers of the Section work in close cooperation with the plant engineers to control the operation of the treatment plants. The behavior of the treatment processes is closely followed. Various operating difficulties are analyzed and corrective procedures are instituted. Inadequacies of present facilities may require changes to structures or the installation of new equipment. Innovations in processes and structures are studied and evaluated. The objective sought is stable operation of the sewage treatment processes, at optimum efficiency.

Increase in B.O.D.

One factor affecting the behavior of the sewage treatment processes, depending as they do upon the activities of varying cultures of microorganisms, is the character of the sewage received at the plants. Considerable interest has been aroused by the change in the character of the sewage received at the Wards Island, Tallmans Island, and Bowery Bay sewage plants during 1949. The change showed up as a marked increase in the B.O.D. of the primary effluent at these plants without a corresponding change in the concentration of suspended solids. At Wards Island, the B.O.D. of the primary tank effluent increased from 77 p.p.m. in 1949 to 106 p.p.m. in 1950, although the suspended solids only increased from 89 to 94 p.p.m. At Tallmans Island, the B.O.D. increased from 83 p.p.m., to 111 p.p.m., as against a suspended solids change from 76 p.p.m. to 79 p.p.m. At Bowery Bay, where the change occurred early in 1949, there was an increase in B.O.D. from 116 p.p.m. in 1948 to 132 p.p.m. in 1949, whereas the suspended solids decreased from 94 p.p.m. to 93 p.p.m.

Coincidental with the increase of primary effluent B.O.D., there has been an increase of air requirements for the activated sludge process at these plants. At Tallmans Island, where the air ratio has averaged 0.36 cu. ft. per gallon for the period 1943 through 1949, 0.50 cu. ft. per gallon was required in 1950, and even higher air ratios are indicated in 1951. At the Wards Island plant, where the air ratio averaged 0.5 cu. ft. per gallon for previous years, activated sludge now requires 0.7 to 0.8 cu. ft. per gallon. As the air requirements for the activated sludge process increase, the economies offered by the modified aeration process, with its lower air ratios, become more attractive. Previous trials with modified aeration have been made at Wards Island and Bowery Bay with partially successful results. Various operating difficulties and a policy of obtaining maximum treatment efficiency from these plants had led to the return to the activated sludge process.

In 1950 however, it became important, because of the higher air requirements encountered in operating the activated sludge process, to institute further studies of modified aeration at the Wards Island and Bowery Bay plants. The objectives of these studies were to determine the factors necessary to successful operation of modified aeration when applied to primary effluent and to study the mechanisms of the process. At Wards Island,

one half of the plant is now successfully operating on modified aeration. About 110 m.g.d. of primary effluent is being treated at an air ratio of 0.4 cu. ft. per gallon; a final tank effluent averaging about 25 p.p.m. of suspended solids and 30 p.p.m. B.O.D. is being obtained.

At Bowery Bay, the reduction in the volume of excess sludge resulting from use of modified aeration has been very advantageous to the operating of the sludge digestion tanks. However, difficulties are being encountered there in treating, by modified aeration, a primary effluent with a high B.O.D. and a low suspended solids concentration. Studies there are continuing.

At the Jamaica plant, where no primary tanks are provided and where raw sewage is being treated, modified aeration operates at an aerator concentration of from 600 to 900 p.p.m. suspended solids. Where primary effluent is being treated, however, it appears to be necessary, especially at higher sewage temperatures, to maintain low concentrations of aerator suspended solids, of the order of 200 to 300 p.p.m., to prevent the development of unsatisfactory conditions. For successful operation the finely divided sludge particles in the aerator effluent must coagulate rapidly and completely when introduced into the final settling tanks, and the settling tanks must allow sufficient time for the coagulation and separation of the solids.

Final Tank Changes

The New York City sewage plants are equipped with a variety of differently arranged final settling tanks. The Wards Island final tanks, as altered by the Design Division, are now effective in providing a good, stable final effluent. These tanks now have an effective length of 170 ft. from the entrance baffle to the opposite end wall. Aerator liquor enters under the baffle, flows along the bottom, drops the return sludge into the center hopper and then rises toward the effluent weirs at the far end of the tank, where the final effluent is removed. Because of the long length of path from inlet to outlet, these tanks are effective in preventing floc from being carried over the effluent weirs by high-velocity currents set up when liquids of varying density enter the tanks. The changes in density are caused by leakage of saline river water in varying amounts through tide gates into the intercepting sewer.

The Tallmans Island final tanks are also affected by varying salt content of the sewage. With the value of long final tanks demonstrated at Wards Island, the flow path of several final tanks was lengthened by dividing the tank into an inlet and outlet section by means of a wooden curtain wall. Flow travels down the inlet section, depositing the sludge in the sump. The liquor then goes around the open end of the curtain wall into the outlet section and travels up the section to the effluent weirs. Analysis of the operation of the Tallmans Island U-path final tanks, now in operation over a year, indicates improved performance with respect to effluent quality.

To insure proper performance by these tanks it is necessary to prevent accumulation of sludge blanket in the outlet section. This is accomplished by close control of the "cylinder" (the 30-min. cylinder settling test performed on aerator effluent). The activated sludge operation is controlled to provide a maximum cylinder of about 16 per cent. When the cylinder increases above this value, the gates provided for step aeration are manipulated. The flow to the various passes is shifted to restore the equilibrium between aerators and final settling tanks. The shift of flow lowers the concentration of suspended solids in the aerator effluent without decreasing the amount of solids in the aeration tanks.

FIGURE 5.—Foaming of Tallmans Island plant aerators.

Foaming

An unexpected dividend of step aeration is its ability to control foaming in the aeration tanks when activated sludge is being used. From about the middle of 1949, aeration tanks have shown an increased tendency to foam. The foam deposits grease on the aeration tank walks and ruins nearby lawns. In conventional activated sludge the foaming is most severe in the final passes of the tank (Figure 5). By introducing primary effluent into these passes foaming may be minimized. Studies by the Laboratory Section on the use of chemical anti-foaming agents to control this condition are being continued.

III. Repair and Maintenance of Mechanical Equipment and Structures

By Richard C. French

Engineer in Charge

Sewage treatment equipment and structural repairs fall into two categories: (1) those required due to regular wear and tear, and (2) those required due to accident, rough usage, or just chance. Under the latter category would be such items as sludge boat accidents, damage to docks, early failure of ball and roller bearings, smashing of equipment when limit switches fail to operate, broken shafts, broken pipelines, flood damage, etc. The amount of this work is more or less unpredictable.

The frequency of repairs under the first category varies, of course, with the type and make of equipment and with loading and rate of usage. The

following represents roughly the experience of this Bureau: Repairs have been made often enough and on schedule so as to prevent shutdowns of any necessary treatment unit except for the minimum time required for the repair or replacements.

Regulators at Intercepting Sewers

All regulators that control the flow from combined to intercepting sewers require more or less continuous maintenance to keep float controls, sluice gates, and tide gates free of timber and rubbish that collects and keeps them from working and seating properly. Replacement of manhole covers and repair of float controls, control valves, and hydraulic cylinders are taken care of in conjunction with regular cleaning operations. At present there are 89 regulators. These are maintained by a force of five men with an emergency truck. Because practically all of the sluice gates are hydraulically operated, their maintenance has been reasonably small. In a few cases it has been necessary to repair water lines. In one case, at a railroad yard, electrolysis was stopped by installing a Micarto nipple at the water main and another at the regulator and pouring a thick layer of asphalt around the pipe between these two points. After the regulators were in use for about 8 years, it became necessary to gradually repair and replace tide gate seats and eroded concrete. After 14 years, about 30 per cent have been repaired in this manner. It would probably be advantageous to have a special mix of concrete with small-sized aggregate poured around gate frames during installation.

Bar Screens and Trash Racks

The Bureau has three types of mechanically cleaned bar screens: (1) The type that is front-cleaned by one or more rakes moved by chains on sprockets; (2) the type that is front-cleaned by a reciprocating rake operated by cables; and (3) the type that is back-cleaned by a number of rakes operated by chains on sprockets. All three give reasonably satisfactory service. They require a more or less complete overhaul after 8 to 10 years of intermittent operation, which probably amounts to from 2 to 4 years of continuous operation. The main replacements are chains and sprockets after about 9,000 to 16,000 hr. of use, and screen bars, back plates, and guides or guide facings after about 32,000 hr. of use. A curved metal guide can be used at the bottom in place of sprockets for the chain. This gives better service and is easier to replace. In the case of cable-operated screens, it is necessary to replace cables after about 6 months. It has been found that galvanized cable will last as long or longer than stainless steel for this particular service.

The back-cleaned bar screen probably clogs or jams the least and, therefore, is less subject to accidental damage. However, if the bars are not made oversize and very rigid they will bend and remain out of shape, and will pass much larger material than intended. The back-cleaned type is probably the best for trash racks, because the bars can be heavy enough to resist bending. Also, large objects will not jam the rakes.

Grit Elevators

The chain-type grit elevators require replacements after about 12,000 hr. This includes chain, tracks, and lower shafts, sprockets, and bearings. Top sprockets and shafts last about twice as long. Rubber belt bucket elevators with only a top pulley require replacement of belts and buckets after about 8 years. Pulleys last longer, provided they are very securely attached to the shaft. If not properly protected from grit, the shafts and bearings require replacement every two years. The steel housings for grit elevators and bar screens begin to

need replacement of plates after about 10 years. It is recommended that the plates should be at least ¼ in. thick to give long life. At splash points the thickness should be ½ in.

Collectors

Repairs to collectors in grit channels, primary tanks, and final tanks constitute one of the major replacement items. In fact, in some cases it amounts to almost complete replacement after 10 years. Speed of operation and location, whether in grit chamber, primary tank, or final tank, will affect the length of time between repairs and replacements. In the case of chain-operated collectors, nearly all parts are resistant to corrosion; but there is considerable movement and rubbing of one part against another, which causes the major wear. The use of stainless steel pins, as a rule, will not extend the life of the chain, because the barrels of chain links will wear faster than the pin. In general, for chain-operated collectors, the grit chamber equipment will last about half as long as primary tank equipment; final tank equipment will last about two-thirds as long as primary tank equipment. This is based on the use of No. 720 chain, or equal, and on the following lengths of tanks and speed of collector flights: Grit chambers—length about 60 ft., speed 4 to 5 ft. per min.; primary tanks—length about 125 ft., speed 2 ft. per min.; final tanks—length about 90 ft., speed 3 ft. per min. Roughly, the life of the sprockets varies inversely with the speed and the life of the chain varies inversely with the speed and directly with the length of the tank. By using split sprockets, they can be reversed when new chain is installed. This presents almost new surfaces at points of contact with the chain, prolonging the life of the chain and sometimes almost doubling the life of the sprockets. Also, in cases where the shafts and bearings do not wear as quickly as the sprockets, much labor can be saved when it is necessary to change sprockets. In primary tanks, repairs and replacements occur about as follows: Chain and sprockets require repairs and replacements after about 8 to 10 years. Bearings must be rebabbitted and shafts built up or replaced after about 8 to 12 years. Replacement of shafts and bearings with new parts is sometimes cheaper than reconditioning the old. Drive chains and sprockets last about one-third as long as the collector chains unless they receive some lubrication, in which case they last much longer. Although malleable iron chains resist corrosion better, steel roller chains will last longer as drive chains because of less friction and the life of the drive sprockets will almost be doubled. Except for accidents, flights will last at least 10 years. If they are made of steel, they should be painted frequently. Wearing shoes should be replaced before they are completely worn out, as this will save other parts of the equipment. Tracks require resurfacing or replacement after about 10 years.

Center-drive round tank collectors have the least amount of frictional wear, but because they are made of structural steel they must be painted every 2 or 3 years or the metal will corrode and a complete replacement will become necessary. The circular collectors with a reciprocating truss to fit square tanks give more trouble because the drive, rollers, shafts, and bearings wear and need replacing. The life of the sliding and rotating parts varies from 3 to 12 years.

Sewage Pumps

Repairing of the larger sewage pumps occurs approximately as follows: Wearing rings and shaft sleeves require building up and replacement after about 13,000 hr. Repairs of thrust and line bearings may become necessary after about 20,000 hr. After about 36,000 hr., it will become neces-

sary to patch impellers or build them up. Few bronze impellers are used in the city's plants, but indications are that they wear less and last much longer than cast-iron impellers. It will take from 40,000 to 50,000 hr. for pump casings to reach a point where they will need patching and repairs. Flexible and fixed couplings begin to need replacements about the same time the impellers need patching. Since the first modern plant in New York City went into operation in 1935 only a few pieces of shafting have required replacing. In a few cases, impellers and bearings have become loose on shafting, requiring that the shafts be built up by metal spraying. Plain, simple, felt grease seals on vertical shafting have proven to be much better than spring-backed composition or leather seals, as they cause less heating of shaft and bearings and can be replaced without dismantling the shafting.

The pump impeller shown in Figure 6 is from one of the 48-in. double-suction sewage pumps at Wards Island. These pumps have each been in operation about one-half the time over a period of 14 years. New oversized impeller rings were installed about six years ago and a similar job had to be done during the present repair. In addition, the stainless steel shaft sleeves had to be built up. At this time, it was found that cavitation had worn deep pits, which in a number of cases had become holes all the way through the blades. The pits were filled in by arc welding with low-temperature alloy cast-iron welding rods. At the holes the metal was cut back to thicker metal and properly shaped castings were welded in place using the same rods. By doing only a small amount of welding at each location at one time, a satisfactory repair was obtained without cracking the impeller and without preheating. Repair in this manner cost about one-eighth as much as a new impeller.

Blowers

In general, centrifugal and rotary blowers, except for motors, have needed practically no repairs for as long as 50,000 hr.

Engines

Repair work on engines at first consists mainly of reconditioning valves, fuel and ignition systems, governors, and instruments. Inspections are also made to determine whether bearings and various parts are beginning to

FIGURE 6.—Impeller of 48-in. double-suction sewage pump after half-time service during 14 years, showing:
Left—Pitting caused by cavitation.
Right—Rebuilding of impeller by welding and cast-iron inserts.

wear or go bad. After about 16,000 hr. the large slow-speed gas engines require refitting of bearings and the replacement of a few bearings, usually crankpin bearings. Also, some or all of the piston rings are replaced. Normally, the first major overhaul is made after about 24,000 to 30,000 hr. This requires new piston rings, valves, rocker arm and pushrod bushings, also some honing of the crankshaft, pistons, and cylinder liners to remove scoring and restore roundness. After about 45,000 hr., it becomes necessary to true up pistons and piston ring grooves and to replace wrist pins and bushings due to normal wear. All babbitted bearings should probably be replaced at this time, because by this time the metal becomes badly fatigued and it is better to avoid possible damage to the crankshaft. The diesel engines on boats require similar work about one-third oftener than the gas engines at the sewage plants. After about 36,000 hr., these engines require replacement of cylinder liners. In our case, a large number of engines have been in use for more than 40,000 hr. in a period of 10 years or more and repairs and replacements of crankshafts have just started to become necessary. Also, in some cases where the top of the seating grout is not kept higher than the rest of the foundation, oil leakage works its way between the engine base and the grout. Due to the vibration of the engine, a pumping action is caused on the oil and the oil washes out fine particles of cement until the space becomes too great and the engine has to be regrouted.

Sludge Pumps

There has been considerable variation in the length of time between repairs and replacements for plunger-type sludge pumps. This is probably due to variations in the amount of abrasive materials in the sludge at the various plants and to variations in the working pressure. An important item that can greatly prolong the life of the plunger sludge pumps is the packing. At present, the period between repairs has been lengthened and the labor involved in keeping the pumps packed has been reduced more than 50 per cent by using a rubberized fabric ring packing cut on the diagonal.

Damage to shafts and bearings has occurred from time to time when sand or a valve ball lodges under one of the plungers. Shear pins located between the gear reducers and the pump shaft tend to reduce this damage. In general, it can be expected that valve seats, cylinders, cylinder liners, or plungers will require replacing, that eccentrics will require resurfacing or replacing, and that eccentric yokes will require rebabbitting, after 10,000 to 15,000 hr. of use. Wrist pins and bushings require replacing after about 5,000 hr. The value of by-pass relief valves is doubtful. The life of the gears and other moving parts in the crankcase of horizontal double-acting high-pressure piston sludge pumps has been increased by making the piston rod longer and installing a deflector on it to keep the sludge from getting into the crankcase. Horizontal centrifugal sludge pumps with two large rounded passageways through the impeller have given very good service on heavy sludge (5 to 11 per cent), as have screwpeller pumps. Shaft sleeves require replacement after about 5,000 hr. of use. Impellers and wearing rings require building up or replacement after about 10,000 hr. The large, slow-speed, low-head centrifugal return sludge pumps wear at about half the rate of sewage pumps. Vertical centrifugal pumps are not recommended for sludge because they tend to become air or gas bound.

Diffuser Plates

In the aeration tanks, considerable trouble has developed due to clogging of the diffuser plates. At Wards Island, 40-porosity plates clogged in

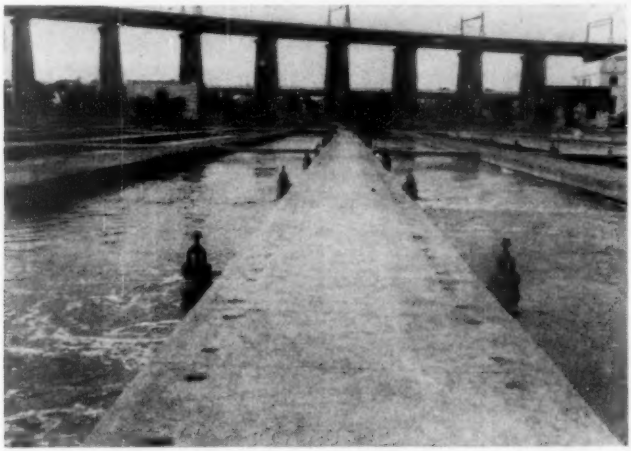


FIGURE 7.—Clogged diffuser plates at Wards Island plant passed less air than required for treatment.

about 20 months, after passing about 3,200,000 cu. ft. of air per plate at a rate of about 4 cu. ft. per min. per plate. At Bowery Bay, 50-porosity plates clogged in about 6 years after passing about 10,000,000 cu. ft. of air per plate at a rate of from 2.5 to 4.5 cu. ft. per min. per plate. At full blower pressure (about 9.5 lb. per sq. in.) the amount of air that would pass through the plates was less than that required for treatment (see Figure 7).

After studying the problem, a method for quickly cleaning the diffusers in place was worked out and permission was obtained to try it. It worked very well. Briefly, the method consists of removing top clogging by spalling off the top clogged layer of the diffuser (Figure 8) and then high-pressure jet washing with the aid of wetting agents and detergents to remove bottom clogging.

The plates at Wards Island, which had the worst condition, were spalled and then jet washed. By repeating the jet washing every four to six months the blower pressures could be kept below 7.5 lb., with resulting power saving. The spalled plates have now passed more than 4,500,000 cu. ft. each, or more than the amount that originally clogged the plates, and the pressures are still low (Figure 9). The deepest spalled plates are the easiest to clean.

At the Bowery Bay plant, bottom clogging was not too great because atmospheric conditions are probably better and because of the use of electrostatic-type air filters. For this plant, spalling alone was satisfactory. More than a year and a half after spalling, the required air pressures are still practically the same as for new diffusers.

To spall and do three jet washings to keep the Wards Island diffusers clean to date (about 22 months) has cost about $1.30 per diffuser for 18,000 diffusers. This results in a saving of about $75,000 over the cost of replacement with new diffusers. Also, during this time air pressures have been kept very close to that required for new plates, causing considerable saving in power. With plenty of air available, better treatment of more sewage was possible. The effluent was better and about 20 per cent more

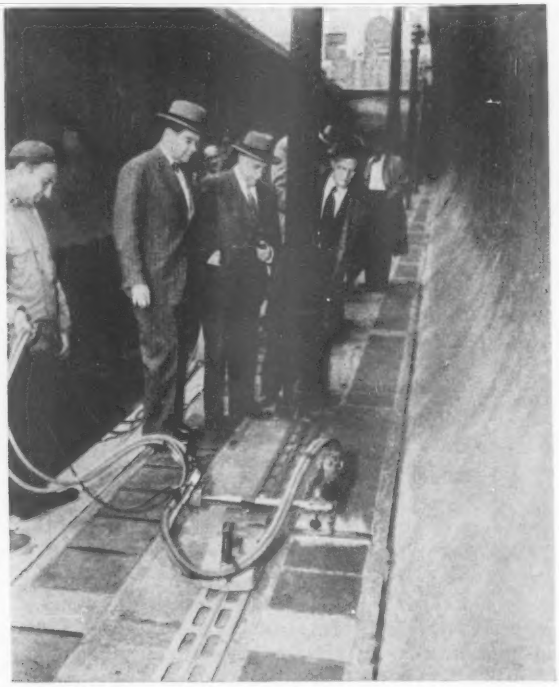


FIGURE 8.—Spalling clogged diffuser plates before jet washing.

boatloads of sludge were removed from Wards Island than in the previous four years. Adequate air supply was a contributing factor.

Miscellaneous Pumps

Repairs on small pumps for hot water, cooling water, effluent water, seal water, boiler feed water, etc., have been minor. Within a period of 10 years most of the piston pumps have required valves, packing, and cylinder liners. Also, within this period about half of the centrifugal pumps have needed shaft sleeves at the packing boxes and a few have needed bearings.

Sump pumps require more extensive repairs, depending upon location. Sometimes a float switch will stick and by running dry the pump wears out quickly.

Vents

One of the troubles with Venturi tubes is caused by trapping of air in the sewer main. To eliminate this, running vents were installed. In this way, the air is continuously vented and a small flow of sewage keeps the vent pipe clean. An extension of the vent pipe with a restricted opening prevents sewage from being blown out with the air and creating a siphoning action that would cause too much flow of sewage through the vent pipe. Due to the nature of sewage, a vent that does not flush itself clean will clog very quickly with grease, rags, and other debris. In large vent pipes, this clogging material will blow out at intervals when the air pressure builds up. The vent will then act like a geyser and shower the surrounding area with sewage.

Chlorinators

Repairs to chlorinators and chlorine equipment will vary, depending upon the attention given to the equipment. Neglect can result in much damage almost over night. Special precautions should be taken to prevent water and moisture from entering any part of the chlorine system up to the point where it is mixed with water. With care, repairs should be reasonably small. Only one bad leak has been experienced and this occurred when everyone was away from the leak and the chlorine could be shut off at a distance. The leak was caused by moisture inside a chlorine evaporator tank, which caused a hole to be eaten through the side of the tank.

Plastic Weirs

Due to heavy doses of chlorine, the Everdur bronze slotted weir plates on the round settling tanks at the Coney Island plant were eaten away. These were replaced with V-notched weirs made of Formica about 5 years ago. There has been no sign of deterioration to date. Also, there seems to be much less tendency for slime to attach itself to the weirs and they remain comparatively clean.

Digestion Tanks

In digestion tanks there has been corrosion. It appears that the main corrosion is due to galvanic action, with the liquid acting as an electrolyte. This corrosion varies with the diameter of the digestion tanks, being greatest in the case of smallest diameter. Repairs and replacements have been necessary on the center towers, tie-rods, steel bolts, and structural steel pipe supports of the 26-ft. diameter digesters at the Harts Island sewage treatment works and the 54-ft. diameter digesters at the Coney Island sewage treatment plant. About the same degrees of corrosion occurred in 6 years at Harts Island and in 10 years at Coney Island. Cast iron and Everdur bronze show no corrosion. At Harts Island, the chrome nickel cast-

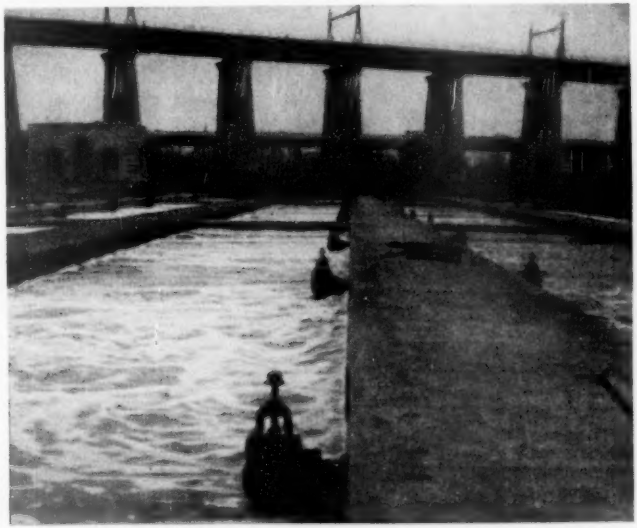


FIGURE 9.—Spalled and jet washed diffuser plates pass required air at economical pressures.

iron heating coil was pitted where the current passed from the coil to the structural steel pipe supports. The side of the pipe support nearest the coil showed little corrosion, but the portion away from the coil was corroded to knife edges. Cast-iron pipe supports were in good condition at Coney Island.

There was practically no corrosion of gas holder shells or interor steel above the liquid level in either case. The lower roller pins, however, necked down where they passed through the brackets on the shells. These pins are being replaced with stainless steel. As repairs become necessary in a digestion tank, all bolts and pipelines are being replaced with Everdue bronze or stainless steel. When structural steel supports and towers are replaced, the cross-sectional areas of the members are made larger. Also, all steel inside of the digester is painted with heavy coats of Bitumastic paint. Little corrosion has been found so far (10 to 12 years) in digestion tanks at the Bowery Bay and Jamaica plants. These tanks are 80 ft. in diameter. At Bowery Bay one digester was drained to fix a broken heating coil and at Jamaica the digesters were opened up to install larger gas lines.

Sludge Vessels

At present there are three sludge vessels in use, each with a capacity of 55,000 cu. ft. of sludge (see Figure 10). It is the policy of the department to use the crews practically full time on trips to sea with sludge. This has required that more than usual repair work be done by contract in shipyard. The work includes the overhaul of engine room and other equipment, piping, propellers, steering equipment, superstructure, hull, various items to meet Coast Guard requirements, etc., and painting of hull and other parts of the vessel. A standard set of specifications has been prepared with about 70 items suited to the work required by the vessels. This is revised slightly

FIGURE 10.—One of three identical sludge vessels used to remove sludge to sea from New York City sewage treatment plants.

each time a repair job is advertised so that it will conform to the known requirements of the vessel to be repaired. The vessels are sent to shipyard about once every year and a half. It has been found necessary to apply five coats of paint to the hull below the water line in order to last this long, but this has grealy reduced repairs and replacements of hull plates and rivets. Also, the use of rolling log fenders instead of floats at the Wards Island dock has minimized denting of the side plates and frames. The vessels have been in use about 14 years. During this time four of the six tailshafts have been replaced and the other two will soon need replacing. The six bronze propellers have been repaired many times and will soon need replacing. One main engine crankshaft broke about a year ago and had to be replaced.

Paint

Paint can do much to cut down repairs and replacements. In the case of paints, it has been necessary to overcome an almost universal belief that red lead was the only paint that was any good to use as a primer or undercoating on metals. The Bureau's experience shows that red lead is probably the worst paint to use around sewage treatment plants. Zinc chromate primer as mixed for use on ships is probably one of the best primers for use in sewage plants. On the sludge vessels, also, it was found that zinc chromate would last better than red lead.

Another paint that has proven to to be very good on rusted and damp metal is a paint with a modified fish oil vehicle. This paint has the disadvantage of taking much longer to dry and of costing more.

It has been possible to obtain agreement that heavy Bitumastic paint is the best for metals immersed in sewage and for the interior of elevator housings, etc. To be really effective, this must be applied directly to the thoroughly cleaned metal. This means that too long a delay in repainting results in much greater cost, due to the necessity for scaling or sandblasting to clean the metal. For about a year, a different bituminous paint has been tried. This paint has the advantage of being thin enough to be applied like a regular paint and does not require scaling or sandblasting to bare metal. It can be applied over other paints and rusted surfaces that have been wire brushed and have had any loose scale removal. It appears that this paint is less porous and will last longer than others that have been tried. Although hot Bitumastic enamel is good, it is difficult to get a contracter to apply it properly.

One of the paints that proved to be very good where abrasion as well as corrosion was present, was aluminum powder in a bituminous base. This was used on the structures under disc screens at the Jamaica and Hammels plants, where it was almost impossible to make other paints last any time at all.

Once a structure has been cleaned, it is better to put on one or more extra coats of paint than to run the risk of having to go to the extra expense of scaling or sandblasting due to the paint not lasting . If galvanized metal, such as gratings, exhaust ducts, and grit elevator housings, are given good coats of paint, it will prolong their life many times. Galvanizing is recommended, but paint will protect it from fumes that attack the zinc. Wherever color is not important, a good bituminous paint should be used. There seems to be no need to repaint cast iron in contact with New York City sewage at the existing plants. Because fumes attack the outside, brass and copper piping should be painted. Also, copper flashing in the vicinity of exhaust ducts on roofs should be painted. It might be mentioned that bronze window and door screens did not last very long and that

plastic screening is being used for replacement.

Conclusion

There are a great many variables that affect the amount of wear on any equipment. Also, pieces of equipment are often used for a considerable time after they have reached a point where it would be justifiable to replace them. Due to the amount of dismantling and reassembling work involved in making repairs or replacements, it sometimes is better to replace or recondition parts that are not fully worn out, along with the badly worn parts.

Availability of funds for the work and time delays in obtaining new materials also have an effect on the length of time equipment is used.

The writer offers the above information only as an approximation of what has been necessary to keep New York City sewage treatment plants in continuous operation. Requirements in any other city or plant would have to be based on its own local and special conditions.

IV. Operation, Repair, and Maintenance of Electrical Equipment

By E. W. Luft

Engineer in Charge

Electric Power

Power for operating the electrical equipment required in New York City's various sewage treatment plants is either purchased from the local electric utility or generated at the plants. In some cases power is partly purchased and partly generated.

At the Wards Island plant, purchased power is delivered at 13,200 v. and reduced by transformers to 4,160 v. for direct application to the main drive sewage pump and blower motors. A further reduction to 440 v. is made for direct application to the various auxiliary drive motors; an additional reduction to 120 v. is made for lighting and fractional horsepower motor drives.

Most of the other plants either generate or purchase power at 4,160 v., the transformation to the lower voltages being the same as for the Wards Island plant. An exception is the Coney Island plant, where the auxiliary drive motors are operated at 220 v.

At the Bowery Bay plant, purchased and generated power are at 208 v. and both the main and auxiliary drive motors operate at this voltage. The same applies to the Tallmans Island plant for the auxiliary drive motors, the main drive units being directly coupled to individual gas engines.

The electric power distribution in the sewage treatment plants may be most easily visualized by comparison with the hydraulic flow through the plant.

High-Voltage Feeds

The starting point would be the incoming power feeders or engine-driven generators, the power flow being to the 4,160-v. busses (at Wards Island, the 13,200-v. busses; at Bowery Bay and Tallmans Island the high-voltage busses are omitted). The high-voltage busses are completely covered with an insulating wrapping, are supported on insulators, and are, in addition, enclosed in a metal structure, only the contact fingers for the circuit breakers and potention transformers not being completely covered. To further assure continuity of service, the busses are sectionalized, so that inspection and, if necessary, repairs to one sec-

FIGURE 11.—Electrical control room at Coney Island plant, showing 4,160-v. busses and switchgear (left rear); d.c. emergency switchboard (right rear); and control benchboard (foreground).

tion may be made without a total plant shutdown.

Closely related to the high-voltage busses and housed in the same switchgear structure are the circuit breakers (Figure 11). These are of the oil filled, solenoid operated, vertical lift type, and may be connected to or disconnected from the busses by means of a rack and gear operated carriage, which holds the circuit breaker. This is an important safety and operating feature, as it prevents accidents by disconnection and removal from the live high-voltage busses. It also permits replacement with a spare circuit breaker, if required, and permits test and operation of the breaker and all related circuits in the dropped or test position, without closure of the primary circuits.

From the circuit breakers, the power flows via the high-voltage cables to the various main drive motors and to the transformers supplying power to the low-voltage busses.

Main drive motors are those operating the raw sewage pumps and the blowers supplying air for the secondary treatment. They are of sufficient size to realize the economies of the higher 4,160-v. windings. Roughly 80 to 90 per cent of the plant power requirements are absorbed by the main drive units.

Low-Voltage Feeds

The power flow from the transformer secondaries is through the low-voltage cables and the low-voltage air circuit breakers before entering the low-voltage busses.

The low-voltage busses, similar to the high-voltage busses, are supported on insulators and enclosed in a metal structure, but are not further insulated, except for a Glyptal lacquer coating to prevent gas corrosion. The busses are also split into two sections to permit inspection, etc., and are generally supplied with separate transformers and feeders to each bus sec-

tion. Duplicate equipment is installed to insure continuity of operation.

The air circuit breakers, installed as part of the low-voltage switch gear, are also generally of the drawout type with the safety and other features of the vertical lift type.

From the low-voltage busses power flows via duplicate sets of low-voltage feeders (one from each bus section) to the various power distribution centers. These consist of a single bus with a manually operated selector switch for drawing power from either of the two low-voltage feeders.

From the power distribution center bus, the power flow is to the various motor starters, generally grouped in the same structure, and via low-voltage cables to the various auxiliary drive motors, such as circulating pumps, air compressors, sludge pumps, flight motors, screen motors, and similar equipment.

From the low-voltage busses power also flows via duplicate sets of feeders (one from each bus section) to duplicate lighting transformers, which reduce the voltage to 120/240 v. The lighting transformer secondaries are usually connected to an automatic throwover switch with a preferred and an emergency position. Interruption of the preferred source of power causes the switch to automatically connect the lighting load to the other transformers, with a return to the preferred position upon restoration of service.

The low-voltage lighting busses are energized via low-voltage cables from the automatic throwover switch. From the low-voltage busses single feeders carry the power to the lighting panel busses. The various groups of lights, fractional horsepower motors, laboratory equipment, etc., are then supplied via protective circuit breakers from the lighting panel busses.

Emergency Operation

To provide power for the automatic circuit breaker operation and supervision, in case of a plant power failure, and for lighting of essential areas, a 60-cell lead-acid type storage battery is maintained in a fully charged condition, floating at 129 v.

The switchgear signal lights and circuit breaker closing and trip mechanisms are energized from circuits feeding from the battery.

An automatic throwover switch, similar to that installed at the lighting transformers, is arranged to transfer the emergency lighting circuits to the battery during power failure.

The foregoing briefly covers the flow of power through the plant and the principal types of electrical equipment.

Maintenance and Repair Problems

As sewage treatment is a continuous process, the continuing of all equipment in service, or available for service, is essential. A failure of the electrical equipment takes out of service not only the electrical, but also the related or driven equipment.

Because of the excellence of the electrical equipment, most equipment failures are generally other than electrical. Electrical failures, when they occur, are usually the result of:

1. Moisture, gas corrosion, and/or dirt.
2. Lack of, or faulty, maintenance.
3. Defective workmanship or materials.
4. Misapplication or faulty design.
5. Submergence.

The most common failures are generally control failures caused by gas and moisture corrosion, a broken wire, loose connections, faulty relay operation, etc.

To aid in the rapid repair of control failures, there are available, at each of the newer plants:

1. Wiring diagrams including schematics or elementary diagrams, showing the chronological steps in the operation, which can then be tested step by step until the fault is located.

2. Spare parts, including complete relays, where special intricate devices are used.

Continuing failures due to any of the previously mentioned causes, particularly when resulting in expensive and long-time outages of important equipment, are investigated carefully, and corrections are then undertaken.

Preventative maintenance for the larger and more important machines and apparatus has been followed and will require expansion to include more equipment as the plants become older. This work is generally done by contract for the rotating machines and consists of complete dismantling, inspection, and reconditioning as required. Worn parts are repaired or renewed, windings and air ducts ordinarily inaccessible are cleaned and washed, and the complete windings are revarnished. Bearings are checked and air gap clearances and alignment are carefully adjusted. Other equipment is serviced as indicated by the inspection reports or the manufacturers' recommendations.

Specific Failures

Several of the outstanding failures experienced may be of interest.

Generator Overspeed and Cable Failure

The Coney Island plant is dependent entirely upon its own generated power for service. Sparking in the air gap of No. 5 generator was being investigated. The unit had been dismantled and a deformation of the pole faces, apparently caused by overspeeding, had been found. The deformation reduced the air gap. This had occurred shortly after the original installation was made and before the overspeed device was adjusted.

While this unit was dismantled, the feeder cable of No. 4 generator, which was in operation, broke down. The cable failure was caused by overheating, due to close proximity to the hot engine exhaust pipe. As soon as the cable failed, the bus voltage dropped and the voltage regulator called for full excitation, with the result that the generator caught fire. Only the bare copper of the stator windings remained. The No. 6 generator, with a damaged feeder cable (all units being alike), and 3 smaller generators, located in the old plant across the street, were, thenceforth, the remaining source of power available for operating the plant. By reducing the generator load and installing temporary barriers, service was maintained with the No. 6 unit.

The field poles of No. 5 unit were reshaped by hydraulic pressure and the unit was reassembled. At the same time, sufficient spare cable was available at the Wards Island plant. This was used to replace the No. 5 generator feeder cable. The unit was returned to service in about five weeks. All this happened during the war, when priorities were required.

As soon as possible, the generator feeder cable on Nos. 4 and 6 units were replaced. Since then a differential protection scheme has been installed and placed in service on the three generators. A cable or winding failure within the differential zone will now cause immediate trip off and shutdown of the faulty unit.

Motor Collector Rings

One of the major sources of trouble is wear on the collector rings of the wound rotor motors, this being particularly true for the high-speed, 3,600-r.p.m. turbo-type blower motors. The equipment is apparently still in the development stage.

Because of the high rotational speed and the high currents flowing, vibration must be reduced to a minimum. Brush pressures must be carefully maintained to guard against unequal current flow in the different brushes. Cleanliness, with freedom from carbon

dust, is essential. A weekly checkup has been found necessary. In addition, experimentation has been carried on with many different grades of carbon brushes and a satisfactory grade finally has been selected. The carbon brush manufacturers have cooperated in this work.

The motor manufacturers have cooperated in redesigning the ring assemblies. At the Bowery Bay plant tool steel contract surfaces for the ring assembly are now being used.

Fans and cooling systems have been redesigned. At the Jamaica plant the fan, located adjacent to the bearing, commenced drawing oil vapors into the collector ring housing. The fan was redesigned and the air flow reversed.

Because of the high air velocities, frequent winding cleanings are required. As this equipment is not too well adapted for access, major overhaul becomes necessary quite often.

Both at the Bowery Bay and Jamaica plants the collector rings have been replaced one or more times because of wear and the periodic regrinding necessary for maintaining a true running contact surface.

On the new equipment at the 26th Ward and Owls Head plants the collector ring cooling air is directed to the basement. A much more rigid brush rigging support has been developed and it is believed that brush wear and ring maintenance will be considerably reduced.

TIPS AND QUIPS

Tank Dewatering Scheme

At a recent meeting of the South African Branch, Institute of Sewage Purification, a round table discussion of sewage treatment plant practice and problems attracted considerable interest. P. R. Loewenstein, superintendent of the Pretoria sewage treatment plant, described a tank dewatering scheme adaptable for use in other plants. Said Mr. Loewenstein:

> In cases of emergency we use a 3-in. pump for emptying sedimentation tanks. The pump has been mounted on a firm base and the base has been mounted on old coco-pan [flanged (?)] wheels. To get the pump into the tank we have had made a light portable bridge, which can span the settlement tanks. The bridge consists essentially of two channel irons suitably braced and spaced to act as a rail track. In the center of the bridge two short sections of the channels are removable. Above the removable sections is a pulley. A winch at the end of the bridge provides lifting power.
>
> When a tank is to be emptied, the portable bridge is placed across the tank and the pump is placed in position at the end of the bridge. The pump motor is connected to the nearest convenient source of current, sufficient cable slack being used to allow for the pump being lowered into the tank. The pump is then run out to the center of the bridge, the channel sections are removed, and the pump is lowered by means of the winch as the water level in the tank drops.
>
> The cost of the pump, complete with motor and accessories, was just under £200 about four years ago. The bridge assembly cost about £50.
>
> The assembly has been found easy to handle. A tank can now be emptied in one day, whereas formerly it took three to five days using a gasoline pump to start with and buckets and ropes to complete removal of the sludge from the bottom of the tank.

Rabbit Romance

From the Plainfield, Ill., sewage treatment plant comes a touching story of two love-struck rabbits that fell into the grit chambers one evening and were found going around together the next morning—on the pump impeller!

Chlorine Tube Cleaner

A recent issue of *The Digester* notes a suggestion by Louis Ekstrand, superintendent of North Store (Ill.) Sanitary District small plants, that an old automobile speedometer cable be used for reaming out corrosion in copper chlorine feed tubes. The flexibility of such a cable should make it advantageous for getting around bends in the tubing.

Glamorized Garbage

Climax of a drive for community-wide installation of household garbage disposers at Herrin, Ill. [see THIS JOURNAL, **22**, 12, 1535 (Dec., 1950)], came during May, 1951, in an intensive "Clean-Up Week" campaign inaugurated with a large street parade and block party for the entire city. As an added incentive to the sale of the disposers, a local newspaper supporting the drive awarded civic and religious bodies a cash bonus for each sale made by the organization and a grand prize to the club or religious body making the most sales.

Lighting in Accident Prevention

In a booklet on "Lighting and the Nation's Welfare," prepared as a public service by The National Information Committee on Lighting, 1410 Terminal Tower, Cleveland, Ohio, adequate lighting of work areas and passageways is stressed. In the words of the booklet:

> It has long been common knowledge among safety men that nearly one-fourth of all industrial accidents are directly or indirectly attributable to insufficient or faulty lighting.
>
> When a workman groping around for a tool thrusts his hand into a moving wheel or belt which is not plainly seen because of black shadows, poor lighting is to blame. Or, when he trips over an iron bar left carelessly on the floor in a dimly-lighted area, the cause of the accident can be charged to poor illumination. It is reasonable to suppose that had the workman seen the bar, he would not have stumbled and fallen. More than that, in the first place, chances are the bar would not have been left there to cause the accident had adequate lighting of the spot made it plainly visible.
>
> . . . No one likes to work in gloomy, dingy surroundings—or where poor light is a day-in-and-day-out strain on the eyes and nervous system. A person simply cannot do his or her best under such conditions, and dissatisfaction is bound to result.

Further, on the subject of protective lighting, which once again is becoming of concern to plant supervisors, the booklet says:

> Protective lighting is used by industry as an aid in the prevention of accident, theft, and sabotage. In many instances, it may reduce fire risk and provide useful illumination for outdoor work at night. The most effective aid to persons intending malicious property damage is darkness, and it is the object of protective lighting to eliminate this ally of the intruder.

Legal Pitfall

Many operators repair parts or have replacement parts for equipment made locally without ever giving thought to the fact that they may be laying themselves open to patent infringement proceedings. At one time or another this has arisen in almost every plant, particularly under the stress of emergency. Although usually done unintentionally, either practice is illegal under the patent laws. The following points should be borne in mind:

1. Although the process or equipment may not be patented as a whole, some parts of it may be patented.
2. Even if you own the machinery, you are not entitled to repair, build up, or replace patented parts without the permission of the patentee, nor are you legally entitled to have someone else perform these services for you.
3. Anyone furnishing parts for patented items or repairing them with-

out permission of the patentee is subject to damage for infringement. To infringe the patent rights is to take a chance on penalty.

Chain Drive Checkup

An excellent reference booklet (Bulletin 51-7) on installation, operation, and maintenance of chain drives and conveyors has been published by the Chain Belt Company, 1600 W. Bruce St., Milwaukee 4, Wis. Salient points outlined in a convenient check list of "cures for sick chains" are as follows:

As regards chain storage, the booklet has this to say:

When chain remains idle for long periods, it may suffer some deterioration. When a machine is not to be used for some time, it is advisable to remove the chain, thoroughly flush it, coat it with a heavy lubricant, and store it.

Never drag chain across floors or leave it lying exposed to dirt and grit. Wrap it securely and put it away in storage bins. Or, if you prefer, chain can be left submerged in a pail of oil.

Chain is a critical item these days. Give it the best of care!

Symptoms	Possible Causes	Remedies
Excessive noise	Misalignment.	Check alignment and correct.
	Too little or too much slack.	Adjust centers for proper chain slack.
	None or improper lubrication.	Lubricate.
	Loose casing or bearings.	Draw up all bolts and brace casings if necessary.
	Chain or sprockets worn.	Reverse or replace if necessary.
Wear on chain side-bars and sides of teeth	Misalignment.	Remove chain and correct alignment.
Chain climbs sprockets	Poorly fitting sprockets.	Turn sprockets and chain or replace if necessary.
	Severe overloads.	Reduce load if possible; lubricate driven machine.
	Chain worn overlength.	
Broken pins and rollers	Chain speed too high for the pitch.	Use chain of shorter pitch of equivalent or greater strength.
	Shock or suddenly applied loads.	Avoid shocks—easy starts give long life.
Chain clings to sprockets	Incorrect or worn sprockets.	Turn sprockets and chain or replace if necessary.
	Heavy and tacky lubricants.	Clean chain and sprockets and lubricate correctly.
Chain whip	Long centers or high pulsating loads.	Reduce centers when possible.
	Too much slack.	
Chain gets stiff	Misalignment.	Check alignment and correct.
	Improper lubrication.	Remove chain, clean, and relubricate.
	Excessive overloads.	Reduce load when possible.
	Corrosion.	
Broken sprocket teeth	Obstruction—or foreign material in chain case.	Check chain clearances. Drain and clean chain case.
Cotters come out	Vibration and centrifugal force.	Turn chains over so heads of cotters are on inside nearest shafts.

Rain, Rain, Go Away

Ordinary rock salt, used as a cloud-seeding agent, may prove an effective tool in man's attempt to control the fall of rain, according to General Electric weather scientist Dr. Vincent J. Schaefer. However, in speaking before a meeting of the American Physical Society at Schenectady, N. Y., Dr. Schaefer put a reverse twist on the rain-making craze by pointing out that the salt might be used to prevent rain along certain normally rainy coastal regions and enable cloud moisture to be transported to areas farther inland before falling as rain.

The principle involved is one of "overseeding" so that insufficient moisture is available per salt particle. This, in effect, would stunt the growth of potential raindrops sufficiently to prevent them from becoming heavy enough to fall. Movement of the air mass farther inland would enable it to gain more moisture on the way, eventually striking an ideal balance with the number of salt particles and initiating rainfall.

Just off-hand this seems to have potentialities as a means of relieving overloaded storm drainage and combined sewer systems in coastal areas. It also offers a new method of preventing basement flooding. But what about the area where all this moisture finally comes "down to earth"? Maybe we'll need to broaden our concepts of "mutual aid"!

Dealing in Futures

Although delivery prices are not affected thereby, a considerable waiting list has been built up for future delivery of sludge by the De Kalb, Ill., sewage treatment plant. The demand far exceeds the supply, simply as a result of a little effort on the part of Superintendent D. E. Henn.

The sales promotion in this case consists of the beautiful flower beds and lawns of the plant grounds, suitably fertilized with sludge, plus free flower plants and cut flowers for those who visit the plant.

But that's not all. To keep the flower supply always in good condition, and to start new stock in the spring, the sewage treatment works boasts its own greenhouse (see Sewage Works Jour., 21, 6, 1080; Nov., 1949), built with the proceeds from the sale of sludge!

Treading Lightly?

Speculation has been rife since April 24, 1951, as to whether Illinois' S.O.W. H.E.S.S. (Society of Operators Who Have Experience Saturation in Sewage) may have some new affiliate members to induct. On that date the Morris (Ill.) *Herald* carried the headline "CITY COUNCIL TAKES STEP ON SEWAGE"!

COMPLETE JOURNAL FILES AVAILABLE

Three long-time members of the Federation have recently contacted the headquarters office for assistance in disposing of complete files of the Journal. Some bound volumes are included, and reasonable prices have been indicated.

The headquarters office will be glad to cooperate with the prospective purchasers by referring their inquiries directly to the above sources.

Editorials

ST. PAUL WELCOMES YOU!

If sheer determination to entertain an annual meeting of the Federation is any indication, those who attend the St. Paul convention in October will be the recipients of some extraordinary hospitality! It has been ten years since St. Paul began its campaign to become host to the Federation. The sincerity of its invitation has already been proved by the actions and enthusiasm of the local people who are carrying the bulk of the work incident to the meeting.

This annual meeting will be an unusual one for the Federation in that it is the first time (excluding the 1947 joint meeting with AWWA in San Francisco) that a municipal auditorium is used. Although there are many advantages to a meeting that can be centered completely in a single headquarters hotel, the St. Paul set-up will not be unduly inconvenient. Hotels and auditorium are within easy walking range, and the auditorium facilities for the technical sessions are especially good.

Advance interest in the meeting has been gratifying, which forecasts a good registration. It may be too much to expect the record attendance of 904 (Washington meeting, 1950) to be broken, but such a development is not impossible. The technical program—both timely and diversified—is deserving of a large audience.

The meeting will be the first one located west of the Federation's membership "center of gravity" since 1947. Registration from the Middle West and the West should, therefore, be well above the average. One of the principal advantages of St. Paul as a meeting place is the excellence of the transportation facilities that the city enjoys.

The Federation takes great pride in its annual meetings, and spares no effort to make them worth the time and expense involved for those who attend them. When the St. Paul conference is over, we feel certain that a good time—and a profitable time—will have been had by all!

THE CHLORINATION MANUAL

The technical literature on chlorination is undoubtedly among the heaviest in volume of that which exists in all major aspects of sewage and wastes disposal. Searchers for information on the subject have found it difficult to resolve data and opinions that appear to be in direct conflict, and to reach definite conclusions from the research and experience that have been reported.

The Federation's new Manual of Practice, "Chlorination of Sewage and Industrial Wastes"—the fourth of the numbered series initiated in 1946—should find a wide and enthusiastic acceptance. Some 2,500 references were reviewed critically by a competent committee, then screened and evaluated, and summarized into a compact guide, including a selected bibliography of references to approximately 400 key papers and reports. Early drafts of

the committee's compilation were submitted for further critical review to about 125 recognized authorities, whose comments and suggestions were taken into account in assembly of the final manuscript. The result is a noteworthy contribution in both theory and practice.

The efforts of the FSIWA Sewage and Industrial Wastes Practice Subcommittee on Chlorination are gratefully acknowledged. Chairman F. W. Gilcreas, with N. S. Chamberlin, H. A. Faber, and A. E. Griffin, have been engaged on the project for more than five years.

Announcements of the availability of Manual of Practice No. 4 have been sent to all Journal readers, and a substantial demand is anticipated.

TO THE INSTITUTE OF SEWAGE PURIFICATION—OUR CONGRATULATIONS

It was fifty years ago, in 1901, that the Association of Managers of Sewage Disposal Works was formed in England as the first association of its kind in the world. This year, as the Institute of Sewage Purification, the organization celebrated its fiftieth year of service. The occasion was observed in fitting style at the ISP Jubilee Conference at Buxton, Eng., on June 19–22.

A highlight of the Jubilee Conference was the address by John N. Garner, former Chief Engineer of the Yorkshire Rivers Board, now retired, in which he reviewed the formation and progress of the Institute. Prior to 1901, sewage disposal practice in Great Britain consisted mainly of means of application to land with a minimum of nuisance. In that year the Royal Commission on Sewage Disposal, under considerable pressure by many towns which could not employ land disposal, issued a report concluding "that it was practicable to produce by artificial processes alone effluents which might be discharged to streams without fear of causing nuisance."

Quoting Mr. Garner further:

> "Round about 1901 was also an exciting time because of controversies respecting the relative merits and demerits of the so-called bacterial methods of sewage purification; the battle of the tanks, simple settling versus septic, was in progress; and methods of percolation were proving better tactics than mere single or double contacts when dealing with the fluid enemy! During the battle, too, there were camp-followers who succeeded in enticing the 'local self-governors' of a good many districts to part with public funds in exchange for more or less worthless nostrums of patent methods. . . . No wonder sewage works managers sought safety in numbers, by forming an Association. . . ."

Space is not available here to list the many accomplishments and contributions that have come from the Institute and its individual members during the past half century. Suffice it to say that the record reflects honor and prestige to those who are responsible, and that it should give them pride and deep satisfaction.

The Federation, too, is eminently proud of its most venerable Member Association. It has set an enviable example for its counterparts in the United States and elsewhere.

Our sincere congratulations to the ISP!

W. H. W.

Federation Affairs

TWENTY-FOURTH ANNUAL MEETING PREVIEW

Municipal Auditorium, St. Paul, Minn., October 8–11, 1951

★

IN CONJUNCTION WITH
TWENTY-FOURTH ANNUAL MEETING OF
THE CENTRAL STATES SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

★

Timeliness and diversity of technical program content will mark the Federation's Twenty-Fourth Annual Meeting, making it an outstanding attraction for all Federation members, regardless of their particular specialty interests. All of the multitudinous local arrangements required for a successful convention have been carefully attended to in detail by Kerwin L. Mick and his host committee members of the Central States Sewage and Industrial Wastes Association. This activity, when coupled with the work of the Program Committee, promises a meeting of outstanding technical quality and excellent social and entertainment value. Additional interest and enjoyment of the meeting will be presented by the outstanding exhibits arranged by the Water and Sewage Works Manufacturers' Association, designed to provide an opportunity for Federation members to see and discuss the latest developments in sewage and industrial waste works equipment and supplies.

The meeting, as in the last few years, will extend over four days to include all of the top-notch features planned.

THE PROGRAM

SUNDAY, OCTOBER 7

Afternoon

Early Registration—Theater Foyer.
Inspection of Exhibits—Stemm Hall.

MONDAY, OCTOBER 8

Morning

Registration—Theater Foyer.
Inspection of Exhibits—Stemm Hall.
Twenty-Fourth Annual Meeting Called to Order—Theater.
President R. E. Fuhrman.
Welcome to St. Paul
Mayor Edward K. Delaney.
National Water Resources Policy
L. R. Howson, Consulting Engineer, Chicago, Ill., and Chairman, Task Committee No. 1 on Domestic and Industrial Water Supply and Pollution, Water Policy Panel, Engineers Joint Council.
Materials Procurement—Today's Problems
Harvey S. Howe, Director, Water Resources Division, National Production Authority, Washington, D. C.

Afternoon

Psychoda Fly Control at Akron

T. C. Schaetzle, Senior Associate Engineer, Sewage Treatment Works, Akron, Ohio.

Experimental Studies on the Concentration of Raw Sludge

John F. Laboon, Chairman, Allegheny County Sanitary Authority, Pittsburgh, Pa.

Discussion: Frank L. Flood, Metcalf and Eddy, Boston, Mass.

High-Rate Chemical and Biological Treatment of Sewage

Theodore Jaffe, Assistant Professor of Sanitary Science, College of Engineering, University of Florida, Gainesville, Fla.

Discussion: A. J. Fischer, The Dorr Company, New York, N. Y.

A Fundamental Approach to the Activated Sludge Process

Ross E. McKinney, Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Discussion: Gail P. Edwards, Department of Public Health Engineering, New York University, New York, N. Y.

Evening

FAMILY NIGHT ENTERTAINMENT—Theater.

TUESDAY, OCTOBER 9

Morning

The Problem of Plating Wastes from an Electroplater's Viewpoint

A. Kenneth Graham, President, and H. L. Pinkerton, Chemical Engineer, Graham, Crowley and Associates, Jenkintown, Pa.

Discussion: William S. Wise, Chief Engineer, State Water Commission, Hartford, Conn.

Treatment of Phenolic-Bearing Wastes with Chlorine

A. E. Griffin, Director of Technical Services, and N. S. Chamberlin, Sanitary Chemist, Wallace & Tiernan Company, Newark, N. J.

Discussion: Grant A. Pettit, Armco Steel Corporation, Middletown, Ohio.

Disposal of Ammonia Still Wastes

William W. Mathews, Superintendent, Gary (Ind.) Sanitary District.

Discussion: Stanley Mogelnicki, Research and Development Engineer, Waste Disposal, The Dow Chemical Co., Midland, Mich.

Recovery of Chromic Acid from Plating Operations

F. R. Keller, Plant Manager; C. C. Cupps, Engineer; and R. E. Shaw, Plating Supervisor, Standard Steel Spring Co., Newton Falls, Ohio.

Discussion: Don E. Bloodgood, Professor of Sanitary Engineering, Purdue University, Lafayette, Ind.

Noon

ANNUAL FEDERATION LUNCHEON—Hotel Lowry.

Address: "Industry's Investment in Pollution Control"

L. A. Danse, Supervisor, Materials and Processes, Production Engineering Section, General Motors Corp., Detroit, Mich., and Industry Representative, Federal Water Pollution Control Advisory Board.

Afternoon

Fifty Years of Pollution Abatement in New Jersey
Robert S. Shaw, District Chief Public Health Engineer, New Jersey State Department of Health, Trenton, N. J.
Discussion: Morris M. Cohn, Editor, *Wastes Engineering*, and Public Health Engineer, Bureau of Sanitation, Schenectady, N. Y.

Principles of Classification of Streams and Watercourses for Best Usage
Anselmo F. Dappert, Executive Secretary, Water Pollution Control Board, New York State Department of Health, Albany, N. Y.
Discussion: E. Sherman Chase, Metcalf and Eddy, Boston, Mass.

The Interrelationship Between Air Pollution and Water Pollution
Louis C. McCabe, Director, Air Pollution Control District, Los Angeles County, Calif.
Discussion: M. Allen Pond, Chief, Division of Engineering Resources, U.S.P.H.S., Washington, D. C.

Problems of the Greater Winnipeg Sanitary District
N. S. Bubbis, General Manager, Greater Winnipeg Sanitary District, Winnipeg, Manitoba, Canada.

Evening

CENTRAL STATES SMORGASBORD AND BUSINESS MEETING—Hotel St. Paul.

WEDNESDAY, OCTOBER 10

Morning

Sewer System Record Keeping
K. B. Stallings, Plans Engineer, Nashville, Tenn.
Discussion: Lloyd D. Knapp, City Engineer, Department of Public Works, Milwaukee, Wis.

Instruments and Their Application in Industrial Waste Treatment
W. N. Greer, Leeds & Northrup Company, Philadelphia, Pa.
Discussion: Isadore Nusbaum, Supervising Chemist, Sewage Treatment Plant, Detroit, Mich.

Determination of Fair Charges for Industrial Wastes
George J. Schroepfer, Professor of Sanitary Engineering, University of Minnesota, Minneapolis, Minn.
Discussion: Thomas N. Niles, Greeley and Hansen, Chicago, Ill.

Moving Picture—"A Tale of the Twin Cities"
Minneapolis-St. Paul Sanitary District.

Afternoon

Inspection Trip
Minneapolis-St. Paul Sanitary District Plant.
South St. Paul Sewage Treatment Plant.

Evening

ANNUAL FEDERATION DINNER AND DANCE—Hotel St. Paul.

THURSDAY, OCTOBER 11

Morning—Concurrent Sessions

Sewage Operators' Forum

George E. Symons, Leader

Chlorine Conservation by Efficient Operation
Meter Maintenance and Repair
Improving Grit Removal and Sludge Dewatering
Combined Sewer Operation

Industrial Wastes Forum

Clair N. Sawyer, Leader

Control of Process Losses
Operation of Anaerobic Treatment Units
Operation of Aerobic Treatment Units
Operation of Evaporation Facilities

TECHNICAL PROGRAM COMMENTS

Despite the extreme variation in interests of Federation members, the Program Committee, under the leadership of F. W. Gilcreas, has developed a technical program that should attract the attention of all. The timely papers on widely diversified subjects are to be presented and discussed by acknowledged leaders in the various areas of the field. Such topics as new developments, water resources policy, materials procurement, stream classification principles, sewer records, instrumentation, treatment of specific industrial wastes, and determination of charges for industrial wastes, are represented. Many of the problems currently facing municipal and industrial treatment plants in design, operation, and maintenance will be discussed, with opportunities provided for open discussion.

Concurrent forum sessions for operators and industrial wastes personnel on Thursday morning will feature topics selected to provide active and productive round-table discussions.

No area of the widespread field of activity and interest of Federation membership has been overlooked—all have been included in some manner in the program with the object of making the meeting of greatest service to the greatest number in accordance with the progressive outlook and expanding interests of the Federation.

SOCIAL FUNCTIONS

An informal get-acquainted period on Monday evening will feature a program of professional vaudeville talent in the comfortable Municipal Auditorium Theater.

The highlight speaker at the Federation Luncheon, to be held in the Hotel Lowry on Tuesday, will be L. A. Danse, industry representative on the Federal Water Pollution Control Advisory Board. His subject will be "Industry's Investment in Pollution Control." As usual, special tables will be reserved at the luncheon for the Quarter Century Operator's Club.

On Tuesday evening the Central States Sewage and Industrial Wastes

Association will hold a Smorgasbord and Business Meeting in the St. Paul Hotel. This will be an official event for members of the host Association, but guests will be welcome.

The always popular Annual Dinner and Dance on Wednesday evening will be held in the St. Paul Hotel. This main social event of the meeting will feature the presentation of Federation awards. There will be no speeches. Pleasurable entertainment for the remainder of the evening will be provided by dancing to an excellent orchestra. Dress will be optional.

LADIES' ENTERTAINMENT

Special entertainment for the ladies will emphasize the scenic and popular points of interest in and near St. Paul and Minneapolis. Ample time will also be allowed for shopping and individual sightseeing.

A Get-Acquainted Tea Party will be held in the Fiesta Room of the Hotel Lowry on Monday afternoon. The Central States Sewage and Industrial Wastes Association is graciously providing this function.

On Tuesday morning a tour of St. Paul and Minneapolis will visit such points as the State Capitol, the State Fair Grounds, the University of Minnesota, St. Anthony Falls, the Milling District (Minneapolis), several of the beautiful surrounding lakes, and Fort Snelling. Luncheon will be at the Sibley Tea House on the return trip.

Wednesday morning will feature guided shopping tours, followed by a Dutch treat luncheon in the Sky Room atop the Dayton Department Store in downtown Minneapolis.

Regular Federation social events also of interest to the ladies are given under the heading "Social Functions."

INSPECTION TRIP

The inspection trip on Wednesday afternoon will highlight visits to the Minneapolis-St. Paul Sanitary District treatment plant and the South St. Paul sewage treatment works. The former is essentially a large, well-designed, and well-operated primary treatment plant with chemical treatment facilities for low-flow periods. It handles approximately 125 m.g.d. of domestic and industrial sewage. The South St. Paul plant, which actually handles more packing-house wastes than domestic sewage, is in an interesting phase of experimental operation.

Inspection of these modern, noteworthy sanitary facilities under the direction of well-informed guides should prove of profitable interest to all and provide an informative and enjoyable afternoon in the meeting program.

EXHIBITS

The display of sewage and industrial wastes works equipment and supplies planned for the Twenty-Fourth Annual Meeting by the Water and Sewage Works Manufacturers' Association promises to rival or surpass all previous exhibits. All available exhibit space was allocated before mid-July. Twenty-eight manufacturers and suppliers will display their products, and informed company representatives will supplement the exhibits of improved and new equipment with first-hand technical data.

The following companies have already indicated their intentions of being represented in the exhibit:

American City Magazine
American Well Works
Builders-Providence, Inc.
Carter Company, Ralph B.
Chain Belt Company
Chicago Pump Company
Combustion Engineering-Superheater, Inc.
Dorr Company, Inc.
Fischer & Porter Company
Flexible Sewer-Rod Equipment Company
General Electric Company
Hardinge Company
Infilco, Inc.
Jeffrey Manufacturing Company
Johns-Manville Corporation
Lakeside Engineering Corp.
Link-Belt Company
Lock Joint Pipe Company
Pacific Flush-Tank Company
Preload Corp.
Public Works Magazine
Simplex Valve & Meter Company
Walker Process Equipment, Inc.
Wallace & Tiernan Company, Inc.
Wastes Engineering
Water & Sewage Works
Worthington Pump & Machinery Corp.
Yeomans Brothers Company

REGISTRATION INFORMATION

As tentatively established, a fee of $10.00 will cover the men's registration, technical session privileges, the Monday evening Entertainment, and the Wednesday Dinner and Dance. Tickets for the Annual Federation Luncheon on Tuesday will be $2.50, and for the Wednesday Inspection Trip will be $1.00.

In separate tickets, the registration fee (required for admission badge to technical sessions) will be $5.00, and the Wednesday Dinner and Dance $5.00.

Ladies' registration at $10.00 will include the Monday evening entertainment, the Wednesday Dinner and Dance, and all special events for the ladies.

The Central States Sewage and Industrial Wastes Association Smorgasbord is a function of that organization. Therefore, tickets will be arranged by the host Association to cover the event.

Early registration will be desirable to avoid the Monday morning rush. To facilitate this, early arrivals will have an opportunity to register on Sunday afternoon, October 7, from 2:00 to 5:00 P.M., when the registration desk will be open in the Theater Foyer of the Municipal Auditorium. The Manufacturers' Exhibit also will be open at that time, so a leisurely registration and inspection can be enjoyed.

HOTEL ACCOMMODATIONS

Ample hotel accommodations have been arranged for Federation members and guests attending the St. Paul meeting. Hotels at which blocks of facilities

are being made available are the Hotel Lowry, the St. Paul Hotel, and the St. Francis Hotel—all located within three blocks of the Municipal Auditorium.

Rooms will be assigned in the hotel chosen to the limit of the accommodations available there. When all rooms in any one hotel are assigned, reservation requests addressed to that hotel will be referred to either of the other hotels having the accommodations desired. Reservations should be made well in advance, as rooms allocated for those attending the Federation meeting will probably be released to the general public about September 22.

Requests for reservations may be made by letter, and should be addressed directly to the hotel preferred. A map of the hotel locations and a schedule of room rates, together with a reservation request form, are given on the advance notice of the meeting mailed to all Federation members during July.

LOCAL ARRANGEMENTS COMMITTEE

The Local Arrangements Committee, under the chairmanship of Kerwin L. Mick, Chief Engineer and Superintendent of the Minneapolis-St. Paul Sanitary District, is composed of the chairmen of the following sub-committees:

Registration Committee: Arndt J. Duvall, chairman; John Sager, Ben Storey, Arnold Steffes, Milton Rosen, and Herbert P. Orland.

Finance Committee: H. G. Rogers, chairman; Willard Bell and Lyle Smith.

Hotel Arrangements Committee: M. L. Robins and L. J. Bartscher, co-chairmen; George Waters, Kenneth Pett, William J. Wade, and Glen Stroessenreuther.

Inspection Trip Committee: B. M. Storey, chairman; W. H. Cropsey, Keith Larson, Scott Linsley, S. P. Cushman, and Frank Hermann.

Local Host Committee: George J. Schroepfer, chairman; James A. Drake, A. S. Johnson, Norman R. Ziemke, Harry F. Seidel, D. J. Thinsen, and Otto G. Bonestroo.

Entertainment Committee: Willard Bell and Dean Colvin, co-chairmen; and Harry Mayeron.

Ladies Entertainment Committee: Mrs. George J. Schroepfer and Mrs. Kerwin L. Mick, co-chairmen; Mrs. J. C. Sager, Mrs. H. O. Rogers, Mrs. K. M. Pett, Miss Elsie Crenander, Mrs. A. J. Duvall, Mrs. M. L. Robins, Mrs. G. E. Waters, Mrs. L. J. Bartscher, Mrs. B. M. Storey, Mrs. A. M. Steffes, and Mrs. G. A. Stroessenreuther.

Reviews and Abstracts*

Effluent Disposal in DDT Manufacture. By J. Grindley. Reprint from *Industrial Chemist* (Nov., 1950).

DDT is manufactured by the reaction of monochlorbenzene and chloral alcoholate in the presence of sulfuric acid containing 20 per cent free sulfur trioxide. The crude DDT is then purified either by washing with large volumes of water or by neutralization with sodium carbonate after draining off the spent acid.

The first method of purification produces a large volume of dilute acid waste. The second method produces 440 to 550 gal. of strong spent acid per ton of DDT made, the acid containing 55 per cent sulfuric acid, 20 per cent ethyl hydrogen sulfate, 20 per cent chlorbenzene sulfonic acid. In addition, the second method produces 800 gal. of wash waters containing 2 to 6 per cent spent acid and 90 gal. of wash waters from the centrifuges.

Other wastes resulting from the manufacture of chloral alcoholate are 2,700 to 2,900 gal. per ton of DDT of "tower effluent" containing 10 g. of hydrochloric acid per 100 g. of waste and from 220 to 440 gal. per ton of hypochlorite liquor containing an excess of NaOH, 1 to 2 per cent chlorine, and small amounts of sodium chlorate and sodium chloride.

The usual method of disposing of these wastes has been by transportation in tank truck to the coast and dumping into the sea. Tests were made, however, to determine the efficacy of disposal of these wastes by biological processes. The tests indicated that the neutralized strong acid wastes could be treated up to 0.05 per cent concentration on percolating filters and 0.028 per cent by activated sludge before significant deterioration of the effluents occurred.

Treatment of the wash waters and other wastes, mixed in proportion to their flow and neutralized, on percolating filters indicated that wastes containing hypochlorite and chlorate destroyed some of the invertebrate animals, such as worms and springtails, thereby disturbing the biological balance and preventing proper functioning of the filter. Corrective measures were made at the manufacturing plant to remove these materials and prevent the carry-over of finely divided DDT in order that the DDT wastes could be treated at the municipal plant.

E. Hurwitz

Treatment and Disposal of Waste Waters Containing Picric Acid and Dinitrophenol. By R. Wilkinson. Reprint from *Industrial Chemist* (Jan. and Feb., 1951).

In the manufacture of shellite bombs and shells, picric acid and dinitrophenol are mixed in the proportion of 70 per cent picric acid and 30 per cent dinitrophenol or 50 per cent picric and 50 per cent dinitrophenol. Waste waters containing picric and dinitrophenol or shellite are derived from washing of cans and tools used in handling the molten materials, washing of floors and equipment, and washing of cyclones used to extract explosives from vapors carried over from the molten material. Losses of shellite at the plant studied amounted to 128 lb. per 1,000 lb. of shellite made. Experiments were made to determine methods for reducing the intense coloring effect of picric acid, the amenability of these wastes to treatment on percolating filters, the toxicity of the effluents, and the amenability of sludges which had been in contact with explosive to anaerobic digestion.

The most effective method for removing color was by reduction of the nitro groups

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and education institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

in the picric acid with scrap iron and acid. The rate at which reduction occurred was in direct proportion to the acid concentration. Percolating filters could treat up to 20 p.p.m. of shellite or dinitrophenol without any appreciable deterioration of the effluent. Beyond this amount a part of the explosive passed through unchanged and deterioration of the effluent is ascribed to the presence of this explosive. Up to 60 p.p.m. of reduced picric acid and acid could be treated satisfactorily on the filter. Sewage containing picric acid, dinitrophenol, or shellite showed higher bacterial counts than the control, indicating that the deterioration was caused by the unbalance brought about by the destruction of protozoa by the explosive.

Toxicity tests indicate that dinitrophenol is considerably more toxic than picric acid, with shellite intermediate. Effluents from filters treating up to 20 p.p.m. dinitrophenol or shellite were non-toxic. Beyond this toxic effects were produced.

Sludge settled from sewage containing 200 p.p.m. of shellite digested as satisfactorily as the control, although the lag period was slightly longer.

Based on the conclusions of the laboratory and small-scale filter tests corrections were made in the construction and operation of a new shell loading plant, which resulted in the reduction of losses of shellite to a concentration of less than 14 p.p.m. Water usage also was reduced. The waste was treated on percolating filters at the municipal plant, which was altered to accomodate the increased load. Satisfactory effluents were obtained.

The article includes a detailed description of the preliminary treatment and treatment at the municipal plant. Average results of analyses for three months of operation are:

Results (Parts per Million)

	Settled Sewage	Settled Effl. from Prim. Filter		Settled Effl. from Sec. Filter
		1st Week	2nd Week	
B.O.D. (5-day)	135	32	26	21
O_2 absorbed[1]	42	36	35	41
Nitrite, as N	—	6.0	6.5	8.0

[1] By N/80 $KMnO_4$.

E. HURWITZ

The Pista Process for Purification of Water and Sewage. By H. L. BENDEL. Paper read at convention of Verband Schweizerischer Abwasserfachleute (Oct. 22, 1948).

The Pista process for treatment of water and sewage using iron in solution as a cheap and simple coagulation agent is based on the Anderson process of water purification (1880), which was revived in Germany about 1935 as the Niers process, using iron shavings and CO_2 for waste treatment. To obtain iron in solution, cast-iron shavings are mixed with the free CO_2 of the water and CO_2 of the air, using also a part of the calcium hardness and oxidizing the dissolved iron rapidly by the oxygen of the air into ferro hydroxide. The Pista aerotor was developed as an equipment for obtaining a cheap and effective coagulant.

The Pista aerator consists of a concrete tank with half-round bottom equipped with a rapidly rotating mixer developing a down draft and a vertical turnover of the water, which is thoroughly mixed with air. The special construction of the aerator allows a much quicker air input and accomplishes oxygen saturation in 10 to 15 min., or 4 to 12 times faster than accomplished with other aeration methods. The ironization capacity of the aerator varies with the hardness and pH of the water and amounts to about 100 p.p.m. Fe for a treatment period of 20 min. at a pH of 8 and 13° of carbonate hardness of the water. This results in about 200 p.p.m. of ferro hydroxide used as the coagulation and adsorption agent.

Normally, 10 to 20 p.p.m. of Fe, or 20 to 40 p.p.m. of $Fe(OH)_3$, are sufficient to coagulate river or lake water. Sewage requires 2 to 6 times as much. As the Pista aerator produces a concentrated solution of $Fe(OH)_3$, it is sometimes necessary to treat only a part of the flow and mix it with the untreated main flow. When using $Fe(OH)_3$ for water treatment and rapid filtration, a dense and effective inorganic filter skin is formed on top of the sand filter. Experiments revealed that the sand acts as a support of the $Fe(OH)_3$ only and the depth of the sand is of secondary importance. The $Fe(OH)_3$ does not change the pH or the chemical

water characteristics and does not form sludge pockets in the sand filter.

The use of $Fe(OH)_3$ produced from cast-iron shavings is economical, considering that cast-iron shavings contain about 96 per cent of Fe and ferric sulfate about 25 per cent of Fe. When treating ground water containing 0.76 to 0.96 mg. per l. of Fe and 0.33 mg. per l. of manganese, the Pista process reduced the iron content to 0.04 mg. per l. and manganese to 0 mg. per l., while the oxygen content increased from 1.3 to 10.3 mg. per l. and organic material was reduced 69 per cent.

When treating wastes with a high content of suspended matter and colloids, the Pista process accomplished reductions from 50 to 80 per cent. The Pista process appears to be especially suited for the treatment of such industrial wastes as milk, packing, paper, dye, and tanning wastes.

PAUL A. UHLMANN

The New Sewage Treatment Plant of the City of Winterthur (Switzerland). BY H. TESTOR. Reprint from *Feld, Wald und Wasser* (Mar., 1951).

The dry weather flow from this city of 65,000 people and its industries averages 10 m.g.d. Excess flows are acreened through a vertical revolving sieve 12 ft. in diameter with $\frac{1}{4}$-in. slots, and discharged to the Toess River, which has an average flow of about 247 cu. ft. per sec. Dry weather flow passes through a 0.8-in. automatic bar screen, a grit channel 82 ft. long (velocity 1 ft. per sec.), and through 2 tanks each 8 ft. deep and a capacity of 2,824 cu. ft., aerated for grease and oil removal by diffused air.

The sewage is settled in two cone-shaped tanks (Bendel system), each 59 ft. in dia. and 52 ft. deep with a sludge compartment of 2,824 cu. ft. and settling space of 42,370 cu. ft. The sludge is removed to two digesters heated by sludge gas. Excess gas (about 28,000 cu. ft. per day) is stored in a separate gas holder and sold to a nearby industry. An operating building adjoins the digesters and houses the necessary pumping and heating facilities, laboratory, and meters. The plant is operated by two men. Total construction cost was about $9 per capita, of which one-third was contributed by the county.

PAUL A. UHLMANN

Destruction of Cyanide in Waste Waters by Chlorination. BY G. E. EDEN, B. L. HAMPSON, AND A. B. WHEATLAND. *Jour. Soc. Chem. Indus.*, **69**, 244 (1950).

The authors, who are associated with the Water Pollution Research Board of Great Britain, report on their investigations of the conditions under which chlorine reacts with simple and complex cyanides.

It was found that when potassium cyanide is treated with calcium hypochlorite at pH 11 or above, most if not all of the cyanide is converted to cyanogen chloride, which subsequently hydrolyzes without further absorption of available chlorine. This was expanded upon in the paper "Effect of Temperature and Presence of Hypochlorite on Rate of Hydrolysis of Cyanogen Chloride Alkaline Solution", Eden, G. E., and Wheatland, A. B. [*Jour. Soc. Chem. Indus.*, **69**. 6, 166 (June, 1950)]. It was noted that excess hypochlorite greatly accelerated the hydrolysis. At lower pH values additional chlorine was absorbed in excess of the theoretical quantity with formation of nitrates.

Application of hypochlorite treatment to wastes from electroplating is discussed, and results are given for a series of tests made on solutions of some of the metal cyanide complexes commonly wasted from plating operations. Removal of cyanide was found to be rapid for the cadmium, zinc, and copper complexes, but difficult and sometimes incomplete for nickel and iron complexes. No significant difference could be found in the effectiveness of calcium and sodium hypochlorites as sources of chlorine.

Attention is called to the toxic hazard of cyanogen chloride developed during chlorination of cyanides, and the point is made that great care must be taken to prevent its liberation from solutions being chlorinated. In treating large quantities of cyanides difficulty was experienced from the formation and release of objectionable quantities of cyanogen chloride, indicating the need for covered reaction tanks.

D. MILNE

Field Widens for Chemist in Waste Disposal Problems. *Chem. Eng. News*, **29**, 376 (1951).

At the meeting-in-miniature held by the Philadelphia Section of the American Chemical Society on January 18, 1951, many papers on waste disposal were given before the various sections.

Estrada indicated that Connecticut annually is recovering 1,500 tons of fiber and pulp, which had previously reached the waterways. Dechant indicated that wastes discharges from the mines in the Schuylkill River valley (Pa.) had been stopped. Air-borne wastes also were discussed.

R. S. INGOLS

Informed Public Helpful in Solving Pollution Problems. *Chem. Eng. News*, **29**, 1734 (1951).

Many technical problems of pollution of both air and water were discussed by the Manufacturing Chemists Association at a conference in New York City in March, 1951. M. L. Parker described a problem in which manholes were smoking because of the presence of phosphorus in the waste discharged to the city sewers. This was solved by chlorination of the plant effluent to induce hydrolysis of the phosphorus and the formation of a weak acid which does not foam.

Also described were the changes made in operation of an acetate rayon plant in West Virginia in order to reduce the waste load on the South River below Waynesboro, Va. The change was costly, but has been effective in reducing the cost of the rayon as well.

Organic wastes that could be discharged to neither stream nor air have been burned with a catalyst at the DuPont Co. plant at Belle, W. Va. Ordinary non-catalytic oxidation became too expensive in tests conducted on the wastes, because of the very low concentration of the organic materials in the waste discharge.

R. S. INGOLS

Increases in Synthetic Detergent Use Mean Bigger Problems for Sanitation—Symposium of Division of Water Sewage and Sanitation Chemistry. *Chem. Eng. News*, **29**, 1635 (1951).

Schwartz pointed out that the synthetic detergents (syndets) are persistent in their surface active properties at high dilution, in contrast to ordinary soaps whose surface active properties are destroyed at low concentrations. It may be necessary to develop some means of destroying the syndet before discharging it to the sewer or river.

Syndets will, in general, increase slime growths on surfaces, according to Rudolfs and Crosby. The laboratory studies indicated that slides dipped in sewage gained more weight when the sewage contained anionic detergents, but that one cationic detergent decreased the amount of slime in relation to the control.

Elton, Hurley, and Waddams indicated that syndets had virtually no effect on the processing of sewage at Wolverhampton, England, in tests lasting 15 months. The effluent at each stage of treatment, including biological purification, showed no deterioration in quality in the presence of the anionic syndet.

The importance of the above information is pointed up by the fact that more than 1,000,000,000 lb. were produced in 1950 and more than 2,000,000,000 lb. are expected in 1952.

R. S. INGOLS

Paper Problems Have Not Been Neglected. BY HARRY F. LEWIS. *Chem. Eng. News*, **29**, 452 (1951).

Much of the research work on paper production has been involved in the search for methods of producing fiber from wood without having to waste all of the digester liquor. Magnesium, sodium, and ammonium base liquors are being studied and used in the United States in an attempt to get away from the calcium base liquors, which have been so commonly used in the past. The ammonia base liquors can be concentrated and burned, but no recovery is possible at present. The production of paper from wood by a mechanical process permits the elimination of industrial wastes, but yields paper of only limited quality. A semi-chemical process is also finding favor for the production of paper for a corrugating medium and other rough uses.

R. S. INGOLS

Water For Irrigation Use. *Chem. Eng. News*, **29**, 990 (1951).

This is a staff report on the papers presented at a symposium on the subject.

Irrigation water is used to increase productivity of crops, so that the quality of the water is very important for that use. The availability of the water in the presence of neutral salts decreases sharply with increasing salt concentration, because of the increasing osmotic pressure. Beyond this general effect, the various specific ions commonly found in irrigation water, such as Na^+, Ca^{++}, Mg^{++}, Cl^-, SO_4^{--}, and HCO_3^-, may accumulate sufficiently to become specifically toxic to the plants.

Boron, although not generally found in water, is highly toxic to plant growth in concentrations of more than 3.0 p.p.m. The sodium ion tends to clog the soil, whereas calcium and magnesium ions tend to make a soil permeable.

Thus, there is need for obtaining complete information on the quality of the water to be used for irrigation.

R. S. INGOLS

Industrial Hygiene Considerations In Plant Location and Design. BY W. R. BRADLEY. *Chem. Eng. News*, **29**, 1198 (1951).

For many years an adequate water supply has been an important consideration in the planning of an industrial plant location. More recently, the importance of the effect of its wastes discharges has been recognized. Ordinarily, industrial hygiene does not consider liquid discharges, but where these may combine in a stream, either chemically or biologically, to produce H_2S advance planning is needed to prevent a re-occurance and some adjustments in the present set-up are required.

R. S. INGOLS

Nitrogenous Compounds in Sugar Beet Juices. BY ROBERT J. BROWN. *Ind. Eng. Chem.*, **43**, 610 (1951).

This report of the research of the Great Western Sugar Co. upon the composition of Steffen waste water gives the results of the search for by-products which can be developed by the industry instead of spending money upon treatment of the waste for disposal. A number of amino acids common to proteins are present, and the approximate yield that could be developed is given. The article is part of a symposium on the purification of sugar juices.

R. S. INGOLS

Anaerobic Persistance of Phenol and o-Cresol. BY M. B. ETTINGER, W. A. MOORE, AND R. J. LISHKA. *Ind. Eng. Chem.*, **43**, 1132 (1951).

Factors bearing on the resistance of phenolic materials to destruction by natural agencies are of importance because of the difficulty which the presence of trace amounts of such materials causes in the production of a safe palatable water. Earlier work on the destruction of phenols in water under aerobic condition has been published. In this work phenol and o-cresol are observed to undergo complete destruction under anaerobic conditions similar to those that might be encountered in polluted streams or waste lagoons. The end products of such decomposition are presumed to be carbon dioxide and methane. The over-all persistance of phenolic materials studied under anaerobic conditions was found to be significantly longer than the time required for the destruction of such materials in polluted aerobic waters. That microorganisms are responsible for the chemical changes observed is indicated by the greater rate of destruction which occurs upon repeated increased doses of phenol to a dilute anaerobic sewage sample.

The results indicate that controlled storage may be satisfactory as a means of destroying phenol-containing wastes under certain circumstances. Because of the biological nature of the reaction, phenolic material will be transported farther in a deoxygenated stream under ice cover.

R. S. INGOLS

Industrial Wastes. BY HAROLD R. MURDOCK. *Ind. Eng. Chem.*, **42** (1950). *Sulfite Wood Pulp Industry*. P. 71A(June). —This is a review of the influence of water pollution problems on the sulfite wood pulp industry and of the efforts by the industry to cope with its waste disposal problems. The author cites specific examples of pollution abatement orders and states that a vital upheaval in the sulfite wood pulp industry appears inevitable.

The waste disposal problem is difficult because of the size of the industry and the

volume of the waste. Waste liquor recovered from the blow pits of all sulfite mills in 1948 amounted to 8,500 m.g., in which were dissolved 3,000,000 tons of wood. The waste sulfite liquor has a population equivalent of 24,000,000.

More and Better Water for Industry. P. 81A (Aug.)—This article stresses the importance of industrial water supply and emphasizes the value of intelligent forest management. Sewage and industrial waste water reclamation studies in Los Angeles County, Calif., are mentioned.

Distillery Wastes. P. 119A (Sept.)—This is a review of how Kentucky distilleries convert spent mash to a profitable animal food and treat remaining wastes so that plant effluent is not damaging to receiving streams. Data on wastes and treatment are presented.

Aeration of River Waters. P. 73A (Oct.)—The author briefly reviews natural purification in receiving waters and outlines the investigations conducted on artificial aeration of streams. Utilization of stream purification capacity, without overloading, is emphasized.

Abrasive Wastes. P. 111A (Nov.)—The process of grinding and polishing plate glass produces a large volume of a water suspension of powdered glass, silica sand, emery, rouge, plaster of paris, and powdered iron. This waste created a pollution problem in the Allegheny River and treatment was needed. Treatment installed consists of settling basins, which receive the combined waste from the entire plant operation. The effluent has a turbidity of less than 100 p.p.m. and is satisfactory for discharge to the river. The sludge is pumped to a natural settling basin. The sludge is highly abrasive and rubber-lined pumps are used.

The paper continues with a description of another process based on the use of centrifuges for classifying abrasives and handling spent abrasives.

PAUL D. HANEY

Torula Yeast Grown on Spent Sulfite Liquor. BY A. J. WILEY, G. A. DUBEY, B. F. LUECK, AND L. P. HUGHES. *Ind. Eng. Chem.*, **42**, 1830 (1950).

Chemical analyses and vitamin assays were made on samples of dry torula-type yeast produced commercially at a Wisconsin pulp mill. Results of analyses and assays are presented. Samples of yeast grown on spent sulfite liquor are compared with five samples grown on other sources of sugar.

PAUL D. HANEY

Treatment of Radioactive Water by Phosphate Precipitation. BY R. A. LAUDERDALE. *Ind. Eng. Chem.*, **43**, 1538 (1951).

The removal of many different cations from solution in only trace concentrations poses a problem in water or wastes treatment. A check of the solubilities of many ions indicated that more phosphates were insoluble than hydroxides. This study was undertaken to check the effectiveness of a calcium phosphate floc in removing radioisotopes from large quantities of water.

As might be expected from the laws of adsorption and co-precipitation, the removal of the radioactive isotopes was higher with the calcium phosphate at high pH and in the excess of phosphate than with the usual ferric or alum hydroxides (because of the greater insolubilities of the phosphates). The calcium phosphate precipitate can be formed from materials of reasonable cost and can be fed from the same machines normally used in water treatment.

R. S. INGOLS

Removal of Submicron Aerosol Particles from Moving Gas Stream—Condensation Center Effects in Steam Nozzles. BY P. J. SCHAUER. *Ind. Eng. Chem.*, **43**, 1532 (1951).

The disposal of organic material which is radioactive requires incineration as the first step in reducing its volume. However, incineration produces smoke and fly ash which is radioactive and will pollute the atmosphere unless removed. This article describes the equipment studied for the removal of the small particles (less than 0.3 microns in diameter) from the incinerator gas discharge. A specially designed steam ejector (nozzle) removes 99 per cent of the activity from the gas stream. The hot water produced must be treated.

R. S. INGOLS

Treatment of Radioactive Waste by Ion Exchange. By J. A. Ayres. *Ind. Eng. Chem.*, **43**, 1526 (1951).

This article is devoted to the study of a means of treating radioactive wastes from a smaller laboratory.

In order to use ion exchange filters for laboratory wastes, the total ion concentration must be relatively low so that inactive ions do not use up the exchange capacity of the filter in too short a time. The filter must also remove radioactive material in the presence of organic solvents, insoluble material, detergents, and complexing agents.

The paper presents data indicating that under the test conditions the radioactive materials studied were removed from solutions to the necessary degree. The radioactivity was highly concentrated on the resins, which were disposed of by incineration to effect a further 15-fold compaction. This type of treatment would be expensive to operate, but would not require large "cooling" tanks, which would cost much more initially. It was disclosed from the floor after presentation of the paper that other research workers had not had favorable results with a similar research program.

R. S. Ingols

Natural Radioactivity of Water. By S. K. Love. *Ind. Eng. Chem.*, **43**, 1541 (1951).

It is essential to obtain background information on the natural radioactivity of surface and ground waters in order to identify and evaluate radioactivity caused by pollution from waste discharges and by possible bomb bursts.

Sea water has been carefully studied and found to contain 0.08×10^{-12} g. of radium per liter. The bottom deposits are somewhat more concentrated than the water, but the exact reason for this distribution is not known. A large number of spring waters have been tested and the results vary greatly. Some thermal springs contain as much as $500{,}000 \times 10^{-12}$ g. per l., although most normal springs contain only 0.1 to 10×10^{-12} g. of radium per liter.

R. S. Ingols

Summary Report on Water Pollution; Missouri River Drainage Basin. U. S. Public Health Service Publication No. 78 (1941).

This is the second in a series of summary reports on major drainage basin areas of the United States under preparation by the Public Health Service.

In the Missouri River valley, sewage and waste treatment projects estimated to cost more than $149,000,000 are recommended at 677 municipal and industrial locations in 10 states. Initial cost of required municipal treatment plants is estimated at $115,000,000, with approximately $34,000,000 needed for initial cost of industrial waste treatment installations. The latter figure is exclusive of industrial wastes now discharged to municipal sewer systems.

Some 677 sewage and waste treatment projects are needed in the basin, including 593 for municipalities and 84 for separate industries. Municipalities need 356 new treatment plants, enlargements or additions to 181, and replacement of 56 plants. Industry needs 70 new plants, enlargements or additions at 13, and 1 replacement.

The report states that no projects are needed at 338 municipal and 19 industrial locations, but that project needs are undetermined for 81 municipalities and 85 industries. Of the municipalities having sewer systems, 67 per cent also have sewage treatment facilities; of the industries listed, 30 per cent have some type of treatment facilities. A total of 979 municipalities, institutions, and sanitary districts discharge sewage equivalent to a population of 4,855,600, including industrial wastes discharged through public sewer systems. There are also 110 separate industrial outlets discharging organic wastes with a population equivalent of 8,486,500, plus 42 more such outlets for which the population equivalent is unknown.

H. P. Orland

Book Reviews

Architectural Graphic Standards. By Charles G. Ramsey and Harold R. Sleeper. John Wiley & Sons, Inc., New York, N. Y. Fourth Edition, 1951. 614 pp. Price, $10.00.

The fourth edition of this encylopedia of useful building information is virtually a new book, as it is 80 per cent larger than the third edition and only 46 pages of that original material remain unchanged. Continuing with the same purpose and the same graphic form of presenting the data, the book reflects the latest developments in all aspects of building.

A 9-page section on drains and sewage disposal is primarily concerned with installations for residences, camps, and small institutions. Included are design data and criteria for cesspools, septic tanks, tile fields, grease traps, drainage systems, and sand filters.

The index has been expanded to more than 11,000 references, with each of the 566 plates cross-indexed under every conceivable heading for easy location of the standards, facts, and data needed by architects, draftsmen, builders, and engineers to deal with every type and every phase of building.

Techniques of Plant Maintenance—1951. Clapp & Poliak, Inc., 341 Madison Ave., New York 17, N. Y. 223 pp. Price, $6.00.

This volume comprises the text of all papers and discussions at the second Plant Maintenance Conference, held at Cleveland, Ohio, in January, 1951, as well as answers prepared by speakers for the many questions that time did not permit them to answer at the sessions. The combined contents of the current volume and the companion volume for 1950 constitute what is probably the most comprehensive literature anywhere available on the subject of maintaining industrial plants at top operating efficiency.

The book follows the pattern of the conference sessions, being divided into sections dealing with electrical equipment, power plant and heating equipment, small plants, lighting equipment, applied lubrication, and specific maintenance problems connected with chemical, paper, food processing, and metal working plants. General problems applicable in all types of plants are considered in three general sections.

Although the emphasis is on maintenance in industrial plant operation, there are many valuable ideas that can be adapted for use in sewage and industrial waste treatment plants. Primary factors stressed in the current volume are maintenance inspections, records, reports, training, organization, and cost budgeting.

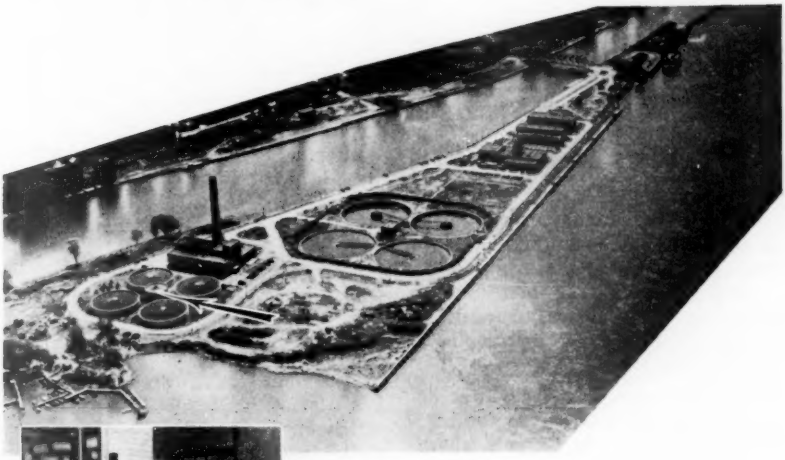
Industrial Water Pollution—Survey of Legislation and Regulations. By Marvin D. Weiss. Chemonomics, Inc., 400 Madison Ave., New York 17, N. Y. (1951). 142 pp. Price, $5.00.

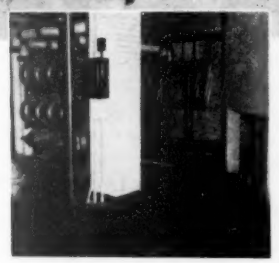
This handbook on water pollution legislation fills a great need of industry for factual, condensed coverage of the subject. Essential aspects of federal and state legislation and regulations are extracted, especially with respect to the effect of the laws upon industrial establishments within each state.

The federal legislation governing water pollution is discussed in some detail. Brief discussions are also given of the various interstate agencies active in this field. Where standards of water quality have been adopted by a state, these are given in their entirety. Four appendices give tabulations of the standards of interstate agencies affecting more than one state. Additional appendices give the membership make-up of various water pollution control commissions by type of organization represented, and a state-by-state listing of the responsible water pollution control agencies.

H. P. Orland

INCINERATORS TEAM UP WITH P.F.T. HEAT EXCHANGER TO HEAT SLUDGE





One of two P. F. T. No. 619 Heat Exchangers which have a designed heat transfer capacity of 2,300,000 B.t.u. per hour each, or a total of 4,600,000 B.t.u. per hour. The sludge piping is so arranged that heat may be applied to any one, or all, of the digesters simultaneously.

At Bird Island Sewage Treatment Works, Buffalo, N. Y.

Two P. F. T. No. 619 Heat Exchangers are installed in the digester control building which is located between the four P. F. T. 90-foot diameter floating cover digesters at the Bird Island Sewage Treatment Works, Buffalo, New York.

Raw sludge is preheated by passing through the sludge tubes of two P. F. T. No. 619 Heat Exchangers. It is inter-mixed with circulated digester liquor to inoculate the raw solids and to eliminate the discharge of cold material into the digesters. With the addition of this modern means of digester heating it is now possible to maintain uniform optimum temperature in all digesters. With high and variable loadings on these digesters, this was not possible with the original internal heating coils.

The hot water circulated through the heat exchangers is supplied from boilers and from the waste heat recovered from the sludge incinerators.

P. F. T. Gas Safety Equipment as described in Bulletin 221 is used throughout to assure safe utilization of the sewage sludge gas. P. F. T. Bulletin 235 gives complete details of P. F. T. Digester Heater and Heat Exchangers for external digester heating.

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Proceedings of Member Associations

ALABAMA WATER AND SEWAGE ASSOCIATION

The Sixth Annual Short School and Conference of the Alabama Water and Sewage Association was held at the University of Alabama, Tuscaloosa, Ala., on June 11–15, 1951. Ne sewage sessions were held the first two days, as there is as yet no plan for certification of sewage plant operators. Total attendance was 113.

On June 13 the sewage session heard papers as follows:

"The Sewage Plant Operator," by A. N. Beck, chief sanitary engineer, State Health Dept.

"Stream Sanitation and Sewage Treatment in Alabama," by J. C. Clarke, assistant sanitary engineer, State Health Dept.

The remainder of the day was devoted to discussions of primary and secondary sewage treatment and laboratory control of sewage treatment plants.

On June 14 an all day inspection trip was made to the sewage treatment plants at Jasper and Gordo. That evening a social hour was provided by the equipment manufacturers.

June 15 was occupied with a general session and business meeting. Papers presented included:

"Fluoridation," by A. N. Beck, chief sanitary engineer, State Health Dept.

"Atomic Radiation," by E. Rodgers, head, Physics Dept., University of Alabama.

"Civil Defense," by Clarence Simmons, State Civil Defense Dept.

At the business meeting J. C. Clarke was named to receive the Federation's Arthur Sidney Bedell Award for 1951.

Officers elected for 1951–52 were:

President: E. E. Love, Tuscaloosa.
Vice-President: C. Hammond, Gadsden.
Treasurer: G. H. Dunstan, University.
FSIWA Director: J. C. Clarke, Montgomery.
Secretary: A. O. Taylor, Auburn.

G. H. DUNSTAN,
Treasurer

CALIFORNIA SEWAGE WORKS ASSOCIATION

The 23rd Annual Meeting of the California Sewage Works Association was held at the Hotel California, Fresno, Calif., April 26–27, 1951. Registration for the convention totalled 250.

The morning session on April 26 included the following papers and talks:

"Latest Developments in Atomic Energy Waste Disposal," by C. W. Christenson, Industrial Waste Branch, AEC, Los Alamos, N. Mex.

"Symposium on Effects of Defense Activities," with O. C. Hopkins, U.S. P.H.S., San Francisco, as moderator.

"Los Angeles County Sanitation Districts Refuse Study; Garbage-Grinding Aspects," by A. M. Rawn and F. R. Bowerman, chief engineer and sanitary engineer, respectively, Los Angeles County Sanitation Districts.

"The Effects of Ground Garbage on Sewage Characteristics," by Russell Ludwig, Ludwig Bros., Pasadena.

"The Pacific Coast Clay Products Institute—Aims and Activities," by John Fredericks, president.

"The Western Concrete Pipe Association—Aims and Activities," by H. W. Chutter, president.

The afternoon session opened with a discussion on "Sewerage Practice in Europe," by a panel comprising Clyde C. Kennedy, San Francisco; Prof. H. B. Gotaas, University of California; and Prof. J. E. McKee, Cali-

(*Continued on page 354a*)

Barbara Fritchie's house in Frederick, Maryland as it appeared in the year 1866

The City of Frederick has a cast iron water main in service that was laid in 1845, seventeen years before Barbara Fritchie's flag-waving defiance of "Stonewall" Jackson's army. The changing channel of a creek undermined her humble home, now replaced in replica to serve as a museum. Yet Frederick's 106-year-old cast iron main, like many others, has survived the changing conditions of a century. Shock-strength, beam-strength and crushing-strength are inherent in cast iron pipe. Because of these strength-factors and effective resistance to corrosion, cast iron water and gas mains, laid over 100 years ago, are still serving in the streets of 38 cities in the United States and Canada.

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FOR WATER GAS SEWERAGE

NUMBER NINE OF A SERIES

fornia Institute of Technology. This was followed by "Observations on Sewer Maintenance in American Cities," by Sydney Preen, superintendent of sewer maintenance, Long Beach, which was discussed by a panel comprising J. L. Carey and Arthur Pickett, Los Angeles, and R. Pomeroy, Pasadena. The session closed with a paper "The Hyperion Activated Sludge Plant—The First Year," by G. A. Parkes, plant superintendent.

The morning session on April 27 opened with concurrent Operators' and Engineers' Breakfasts. The former had as moderators Wayland Jones, superintendent of sewage disposal, Stockton, and Homer W. Jorgensen, consulting engineer, Modesto. Moderators for the Engineers' Breakfast were Paul Ward, sanitary engineer, State Health Dept., and Jack Pratt, Process Engineers Co. The breakfasts were followed by an open forum on "Design and Operation of Sewage Works," with Fred Nelson, The Dorr Co., as moderator.

The afternoon session commenced with a "Symposium on Water Pollution Control," including discussions as follows:

"At the State Level," by Vinton A. Bacon, executive officer, State Water Pollution Control Board, Sacramento.

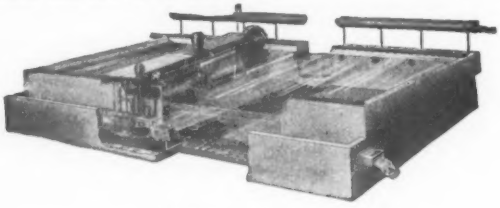
"At the Regional Level," by J. S. Gorlinski, executive officer, Central Valley Regional Water Pollution Control Board.

"Current Legislation," by C. J. Geraghty, executive secretary, State Assembly Water Pollution Committee, Oakland.

(*Continued on page 356a*)

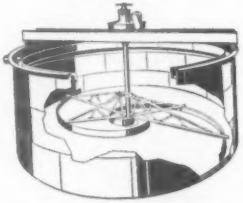
Hardinge WASTE WATER *Equipment*

AUTOMATIC BACKWASH RAPID FILTER



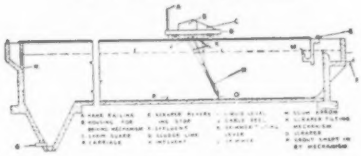
For high removal of non-settling or slow settling suspended matter. Self-cleaning sand bed. No shutdown necessary for backwashing. Bulletin 46-16.

THICKENERS



For removal of fine suspended solids from supply water, waste water and sewage. "Auto-Raise" mechanism prevents scraper breakage. Bulletin 31-D-16.

RECTANGULAR CLARIFIERS



Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. Bulletin 35-C-16.

DIGESTERS

Sludge scrapers and scumbreaker arms prevent scum accumulation, insure uniform gas production. Emit a dense digested sludge. Bulletin 35-C-16.

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is ready to meet your every requirement...

IOWA Motor Operated Gate Valve . . .
Sewage plant influent

IOWA Gate and Check Valves . . .
Sewage pump discharge

IOWA Manually Operated Sluice Gate . . .
Settling basin drain

IOWA'S complete line of gate valves, check valves, flap valves, shear gates, mud valves and sluice gates is specially designed for severe and particular operating conditions in sewage disposal plants, sewage pumping stations or wherever sewage flow control is required. Let us help you solve your problems. Specify IOWA products and get the best.

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Also presented were:

"Sewage Disposal in the San Joaquin Valley," by E. S. Cary, State Health Dept.

"The Fringe Area Waste Disposal Problem," by H. W. Jorgensen, consulting engineer.

On the evening of April 27, conferees and their ladies enjoyed the Annual Banquet, Entertainment, and Dance.

The morning of April 28 was occupied by a "Caravan Trip" to the Fresno waste disposal and sewage treatment plants and to the municipal farm.

SAM A. WEED,
Secretary-Treasurer.

MICHIGAN SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 26th Annual Conference of the Michigan Sewage and Industrial Wastes Association was held at the Pantlind Hotel, Grand Rapids, Mich., June 4–6, 1951. A total of 165 men attended the conference and 45 ladies were present for the social events and an extensive ladies' program.

The June 4 session was of general interest to all conference registrants. It included a message from the State Health Commissioner and the following papers:

"Water, the National Defense Resource," by Milton P. Adams, secretary-engineer, Michigan Water Resources Commission.

"Review of Events—Sewage Treatment," by W. F. Shephard, sanitary engineer, Michigan Dept. of Health.

"Review of Events — Industrial Wastes Treatment," by A. N. Corcoran, engineer, Michigan Water Resources Commission.

"Ventilation of Sewage Plants," by Kenneth Robinson, ventilation engineer, Michigan Dept. of Health.

(*Continued on page 358a*)

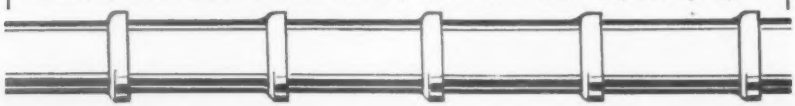
Only vitrified clay pipe can pass the Acid Test

This is no figure of speech. The acid test has been carefully specified by the American Society for Testing Materials. Specimens from vitrified clay pipe are immersed in hydrochloric, nitric, sulfuric, or acetic acid. After 48 hours the acid-soluble matter must not exceed ¼ of 1%!

No other pipe undergoes such a test, because no other pipe can pass it. The test gives you definite, laboratory proof of the superiority of vitrified salt-glazed clay pipe.

Acid conditions occur in *all* sanitary sewers, either from sewer gas or from industrial or trade wastes. Only vitrified clay stands up year after year under this vicious acid attack.

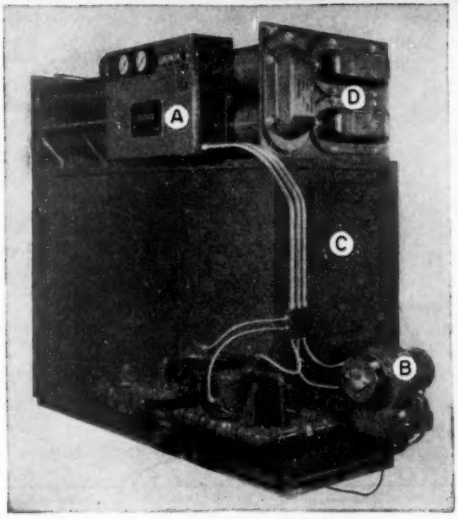
CLAY PRODUCTS ASSOCIATION, 100 North LaSalle St., Chicago 2, Ill.



WALKER PROCESS

HeatX UNIT

Digester Heat Exchanger



All main elements are easily removable for inspection, service or replacement by exchange with factory serviced unit.

A. Package Control Panel

B. Package Burner

C. Package Hot Water Tubes

D. Package Exchange Tubes

Above is the Walker Process HeatX Unit . . . combined Boiler and Exchanger.

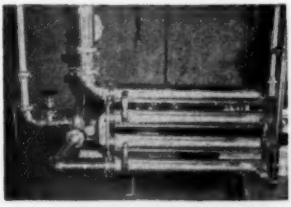
Designed to provide ABSOLUTE CONTROL over each function of sludge heating

Each function is separate . . . easily and accurately controlled.

Sludge pumps provide forced circulation of sludge from digester through heater tubes, and the hot water pump forces uniform flow of jacket water to maintain desired heated sludge temperatures under highly efficient turbulent flow conditions.

This versatile HeatX Unit is adaptable to all existing installations . . . without changing present boiler. We'll gladly supply complete details.

Write For Bulletin 24S24.



Walker Process HeatX Unit installation . . . Separate Style . . . employing existing boiler.

WALKER PROCESS EQUIPMENT INC.

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The session ended with a group discussion of "Operator Training Needs," which was continued several times later during the conference.

In the evening the Annual Smoker was well attended. Refreshments were furnished by the Water and Sewage Works Manufacturers' Association.

An Operators' Breakfast and Roundtable on June 5 was attended by about 75 persons. This was an innovation for this association, but proved so successful that it is planned to continue with the session in succeeding years.

Concurrent sessions were held during the day dealing with subjects of particular interest to sewage works operators and planners in one session, and to those interested in industrial wastes problems in the other. The sewage session heard a paper on "Two-Stage Chlorination—A Practical Means of Disinfection Control," by D. M. Pierce, sanitary engineer, Michigan Dept. of Health. This was followed by a panel discussion on "Development and Execution of Sewage and Waste Disposal Projects," under the chairmanship of Prof. C. J. Velz, University of Michigan; and a paper on "Studies on the Effects of Adding Ground Garbage to Sewers," by I. Nusbaum, City Engineer's Office, Detroit. The industrial wastes session heard papers as follows:

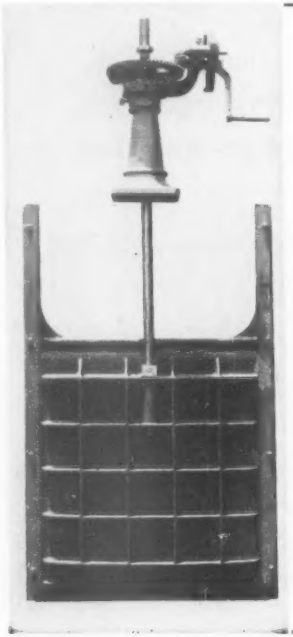
"Operation of Semi-Scale Plant for Treatment of De-Inking Mill Wastes," by A. J. Palladino, engineer, National Council for Stream Improvement.

"Treatment of Board Mill Wastes," by M. F. Knack, chemist, River Raisin Paper Co., Monroe.

"Soluble Oil Waste Treatment at Chevrolet-Flint," by C. Hathaway, metallurgist, Chevrolet Detroit Forge, General Motors Corp., Detroit.

"Joint Water and Plating Waste Treatment Plant at Ford Motor Co., Monroe," by Frank Kallin, Sanitary Engineering Section, Ford Motor Co., Dearborn.

(*Continued on page 360a*)



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AT THE F.S. & I.W.A. CONVENTION

Visit Booths 17 and 18 and see the latest equipment developments for sewage and industrial waste treatment . . .

check... performance curves on Dorr Sifeed Clarifiers for suspended solids and B.O.D. removals.

check... operating results on Dorr Digesters equipped with high-capacity draft-tube mixers.

check... maintenance on Dorr Clarifiers, Clarigesters, Spiral Heat Exchangers and other Dorr equipment.

check... the latest developments in mechanical treatment . . . The Dorrco Aerator-Clarifier . . . the Dorrco Sulzer Disintegrator-Bar Screen combination.

And be sure to stop by and see the detailed scale model of the Dorrco Vacuator and the operating model of the Dorr Type MA Digester. Booths 17 and 18 at the Municipal Auditorium in St. Paul.

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Associated Companies and Representatives in the principal cities of the world

A joint session heard a symposium on "Detergents and Their Influence on Waste Treatment," by Prof. W. L. Mallman, Michigan State College, and W. A. Sperry, superintendent, Aurora, (Ill.) Sanitary District.

Prior to the Association Banquet, a cocktail hour was enjoyed through the courtesy of the Water and Sewage Works Manufacturers' Association. At the banquet, Professor John G. Hays, Michigan State College, spoke entertainingly on "The Mechanical Cow."

On June 6 a joint session was held, with papers as follows:

"Atomic Energy Wastes," by Ralph Purdy, engineer, Michigan Water Resources Commission.

"Studies on the Application of Acid Pickling Liquor in the Activated Sludge Process," by Maurice Richmond, engineer, Michigan Dept. of Health.

"Design and Construction of Sewer Systems," by Millard Moore, city engineer, Grand Rapids.

"Maintenance of Sewer Systems," by Victor Camp, city engineer, Marshall.

At the business meeting, an amendment to the constitution was adopted providing for the addition of a second vice-president to the Executive Committee. Officers elected to serve during 1951–52 were:

President: C. W. Hathaway, Detroit.
1st Vice-President: W. E. Smith, Detroit.
2nd Vice-President: R. D. Craun, Rochester.
Secretary-Treasurer: D. M. Pierce, Lansing.

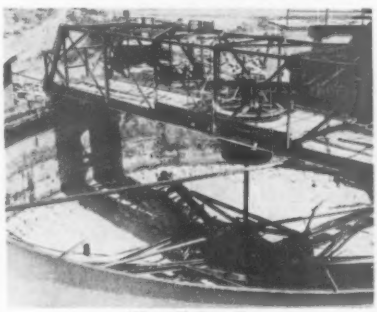
DONALD M. PIERCE,
Secretary-Treasurer

MARYLAND-DELAWARE WATER AND SEWERAGE ASSOCIATION

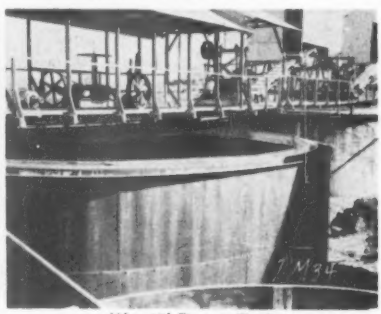
The 24th Annual Conference of the Maryland-Delaware Water and Sewer-

(*Continued on page 362a*)

IMMEDIATE DELIVERY
9 Thickeners and Clarifiers



45′ x 12′ Dorr Co.



40′ x 10′ Denver Equip.

ALL STEEL TANKS — ELECTRIC MOTOR DRIVES

1—50′ dia. x 10′ Eimco, truss-type superstructure lifting device. 3 H.P. 220/440 volt Gearmotor.
1—45′ x 12′ Dorr, low head superstructure (see picture).
2—40′ x 10′ Denver, low head, 5 H.P. Motors.
3—40′ x 10′ Eimco, truss-type superstructures, 3 H.P. Gearmotors (see picture).
2—20′ x 10′ Denver, low head, bolted steel tanks, spiral rakes, 2 H.P. motors.

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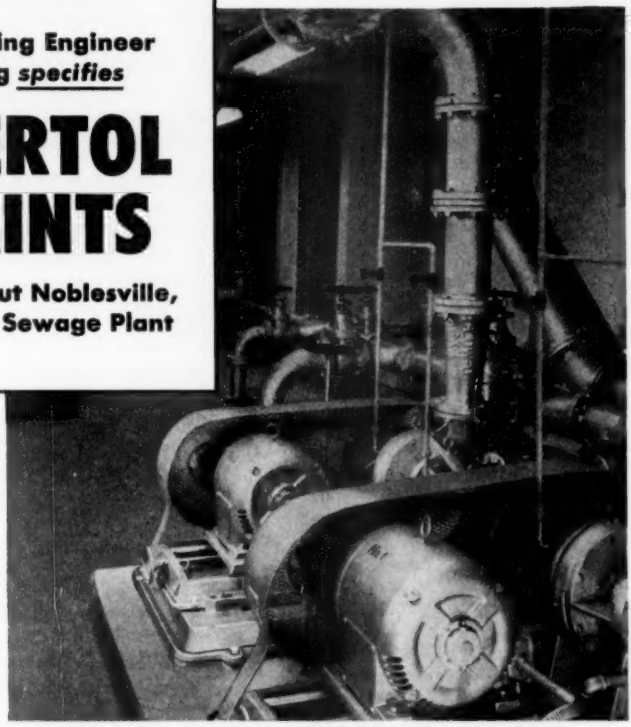
808 Newhouse Building Salt Lake City, Utah

Consulting Engineer Steeg *specifies*

INERTOL PAINTS

throughout Noblesville, Indiana, Sewage Plant



Glamortex, an alkyd resin enamel, provides a durable, mar-resistant finish to piping and machinery.

Ramuc Utility, a glossy, chlorinated rubber-based enamel, protects and beautifies walls, ceilings, concrete and masonry.

● To meet the rigid requirements of durability and attractiveness for this modern sewage plant, Mr. Henry Steeg, Indianapolis consulting engineer, specified the use of Inertol Paints. He knew from experience that these paints would far exceed the demands of hardness, elasticity, chemical inertness and beauty. The superiority of these quality paints, developed specifically for sewage plant usage, has been proved in hundreds of installations throughout the country.

Here is *another* "case history" from our growing file, where expert consulting engineers *specify* Inertol Paints because of the guarantees of long-lasting performance.

If you are not familiar with the merits of this quality line, our Field Technicians will be pleased to discuss it fully with you at your office. Or if you prefer, write us today for the "Painting Guide," an invaluable aid for Design Engineers, Specification Writers, Contractors and Plant Superintendents. Address office nearest you.

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age Association was held at the Commander Hotel, Ocean City, Md., on May 17–18, 1951. Registration for the meeting totaled 167, of whom 26 were ladies.

On May 17, after a welcoming address by Mayor Daniel Trimper, Jr., of Ocean City, papers were presented as follows:

"Chlorides in Shallow Well Supplies," by Oliver Henderson, chief operator, New Castle, Del.

"Cannery Waste Disposal," by N. H. Sanborn, National Canners Association, Washington, D. C.

"Filter Sweeps," by Edward S. Hopkins, Bureau of Water Supply, Baltimore, Md.

"Effects of Sewage on Cattle and Garbage on Hogs," by Arthur H. Cline, chief operator, water and sewage plants, Agricultural Research Center, Beltsville, Md., and Charles W. Snyder, Maryland State Dept. of Health.

"Waterworks Protection, Precautions and Stock Piles," by R. C. Willson, area waterworks coordinator (civil defense), Hagerstown, Md.

"Mobile and Portable Water Filtration Equipment," by Harry M. Lowe, Jr., Water Supply Branch, U. S. Army Engineers, Fort Belvoir, Va.

A short review of Federation activities was given by W. H. Wisely, executive secretary, FSIWA, prior to the Business Meeting, at which the following officers were elected for 1951–52:

President: L. E. McClung, Washington, D. C.
1st Vice-President: V. W. Faivre, Wilmington, Del.
2nd Vice-President: R. H. Ritter, Baltimore, Md.
FSIWA Director: W. M. Bingley, Baltimore, Md.
Secretary-Treasurer: W. M. Bingley, Baltimore, Md.

An enjoyable interlude for relaxation and good fellowship was provided by the Annual Banquet and Entertainment, held the evening of May 17.

The technical session on May 18 included the following papers:

"Sewage Treatment Operating Problems," by L. H. Bean, supervisor of operation, Fairchild Aircraft, Hagerstown, Md.

"Operation and Maintenance of Small Water Pumping Plants," by C. Jorgensen, operating engineer, Bacon Health Center, Delaware City, Del.

"Well and Pumping Equipment Tests," by H. M. Potter, American Well Works, Baltimore, Md.

An open forum conducted by R. E. Fuhrman, president of the Federation and retiring president of the Maryland-Delaware Association, concluded the conference.

W. McLean Bingley,
Secretary-Treasurer

THE MAGNETITE FILTER REMOVES FINE SUSPENDED SOLIDS

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GREATLY IMPROVES EFFLUENTS & EFFICIENCY OF

★ Plain Sedimentation
★ Chemical Precipitation
★ Trickling Filters & Bio-Filters
★ Activated Sludge

The MAGNETITE FILTER removes nearly all settleable solids and 40 to 50% of all suspended solids reaching it. It gives a constant quality of effluent in spite of major variations in influent.

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New Improved Equipment

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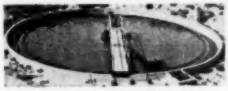
★ PROCESS CLARIFIERS

Numerous successful installations are the result of "know how" acquired by the personnel of Process Engineers Incorporated through many years of experience.

Type B. North Roseburg, Oregon. Diameter 30'. This construction has beams spanning the tank for supporting the rotating mechanism. Used for tanks up to 45' in diameter.



Type C. Banning, Calif. Diameter 45'. The drive unit and rotating mechanism supported on a steel or concrete center column that takes all of the torque.

Type T. Bellingham, Washington. Diameter of each tank 60'. Has a center column for supporting the rotating mechanism and driven by means of a driving walkway or truss with traction wheels rotating on the tank wall. The traction wheels are driven by a gear motor, sprockets and roller chain.

★ PROCESS OXIDATORS

Process Oxidators include aeration, coagulation and sedimentation in a single circular tank giving the results of intermediate treatment at practically the cost of primary treatment. Installation also results in minimum scum handling, higher removal of suspended solids and greater reduction in biochemical oxygen demand with improved clarification, increased grease removal and elimination of odors by maintaining sewage in fresh condition. The Oxidator is suited to processes involving chemical reactions and if followed by a biological filter, reduces the size of the filter because of a reduction in the BOD loading. Three types B, C, and T are available as in the case of the Process Clarifiers.

Type B, Gilroy, Calif. Dia. 45'.

Type T, Chula Vista, Calif. Dia. 55'.

★ PROCESS Automatic Variable Skimmer

Before installation of Process Skimmer

This device automatically skims floating material from the surface of a liquid that varies in elevation by several feet. The difference in elevation between the liquid level and the lip for skimmings is adjustable and will maintain this adjustment during the up and down travel. The device is sensitive within ¼" change in the liquid level.

After installation of Process Skimmer

★ PROCESS CLEANABLE SIGHT GLASS

A "must" for every sewage plant! Consists of a short section of special glass inserted in the piping system to make the contents visible to the operator. A manually operated cleaning device is provided for removal of material adhering to the inside of the glass. A cleaning solvent can be forced against the inside of the glass to facilitate removal of grease, oil, etc. Applicable to sludge lines, supernatant liquor and other applications where it is desired to easily observe the character of the material being handled. Installations reveal how suddenly the sludge from a sedimentation tank changes in density. Helpful to the plant operator in diminishing the amount of unnecessary liquid pumped to digesters.

For complete information without obligation regarding any of the equipment described, communicate with any of the addresses listed below.

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EASTERN AND MIDDLE WESTERN REPRESENTATIVE:
PACIFIC FLUSH-TANK COMPANY • 4241 RAVENSWOOD AVE., CHICAGO 13, ILL.

Equipment and Supply Lines

Automatic Artificial Respiration—A new 4-page bulletin (CH–2) describes the Pneolator, an apparatus providing automatic artificial respiration without suction for safe lung ventilation in cases of respiratory failure. Attachments are available for giving simultaneous treatment to a second patient with individual controls. The unit is compact, weighs only 47 lb. complete, and is equipped for easy carrying.—Mine Safety Appliances Co., Pittsburgh 8, Pa.

Concrete Floor Patcher—An iron asphalt patching material producing long-life repairs by easy, fast patching or resurfacing of worn concrete floors is announced in a new 8-page bulletin on "Masterquick." Proper bonding of the material to the old concrete surface allows feather edges resistant to impact and heavy traffic wear.—The Master Builders Co., Cleveland 3, Ohio.

Pipe Dimensional Data Card—Dimensions on welded fittings and flanges that could otherwise be found only by searching through many catalog pages and tables have been condensed and reproduced on two sides of a varnished letter-size card. Essential dimensions are given for all types of fittings and flanges for nominal pipe sizes from ½ in. through 30 in.—Taylor Forge and Pipe Works, P. O. Box 485, Chicago 90, Ill.

Pocket pH Meter—Completely self-contained with batteries, a new pocket-size pH meter in a camera-type case is available for making rapid on-the-spot pH determinations. Hearing-aid type batteries provide up to 1,300 hours of operation, with the meter scaled from pH 2 to 12 for easy reading. Accuracy of 0.1 pH is claimed to be obtainable with sample volumes of only 0.5 ml.—Analytical Measurements, Inc., 585 Main St., Chatham, N. J.

Valve Actuators—A new line of valve actuators for air, oil, water, or steam operation adaptable to any make, size, and type of valve; to operate against any line pressure; to work on any fluid medium; and with any pressure available, is described in Bulletin 512 which shows typical circuits and details of construction, application, and control.—Ledeen Manufacturing Co., 1602 South San Pedro St., Los Angeles 15, Calif.

Atomic Energy Protective Equipment—A new 8-page booklet (No. G–10) gives details on 22 separate safety items useful in dealing with radioactive and toxic contaminants. Included are sampling equipment, ventilation accessories, protective clothing, contamination control materials, automatic artificial respiration instruments, and oxygen therapy equipment.—Mine Safety Appliances Co., Pittsburgh 8, Pa.

Wastes Sampling—The principles of automatic sampling and flow measurement systems are outlined in a reprint illustrating types of application in industrial wastes investigation and control.—Hagan Corp., Pittsburgh 22, Pa.

Power Operated Plug Valves—Bulletin V–214 is a complete compilation of technical data covering use of pneumatic, hydraulic, and electric operators for lubricated plug valves. Included are typical piping diagrams, arrangements for both side- and top-mounted motor controls, closing speeds, wiring data, and photos of actual installations.—Rockwell Mfg. Co., 400 North Lexington Ave., Pittsburgh 8, Pa.

Protect your sewage plant Investment with "Varec" SAFETY INSURANCE

. . . "VAREC" sewage gas control equipment is safety insurance that you pay for only once! It represents only 1/10 of 1% of your entire sewage treatment plant investment, yet "VAREC" provides lifelong protection against the possibility of fire and explosion.
DIGESTER PROTECTION — "VAREC" Figure No. 5800C Pressure Relief and Vacuum Breaker Valve with Flame Arrester.
GAS HOLDER PROTECTION — "VAREC" Figure No. 280A Pressure and Vacuum Relief Valve.
BOILER PROTECTION — "VAREC" Figure No. 187 Pressure Regulator and "VAREC" Figure No. 450 Flame Trap Assembly.
SYSTEM PROTECTION — "VAREC" Figure No. 440 Pressure Relief and Flame Trap Assembly.
PIPING PROTECTION — "VAREC" Figure No. 70 Explosion Relief Valve.
LABORATORY GAS LINE PROTECTION — "VAREC" Figure No. 52A Flame Check.
PROVED and APPROVED "Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY
COMPTON, CALIFORNIA, U. S. A.

S-11 *Available from Authorized Sewage Equipment Agents throughout U. S. and Canada.*

750,000 pounds of filter cake per day

converted to fertilizer at new Houston Plant

Another step in Houston's long range plans for complete waste treatment was finished last August with the opening of a C-E Raymond equipped, 28,000 tons per year municipal sewage sludge drying plant.

The two new Flash Drying Systems, located at Houston's North Side plant, dry activated-sludge from both the North Side and Sims Bayou plants. Most of the dried sludge is marketed locally for fertilizer but some is shipped as far as the East Coast.

This new plant, designed to serve an equivalent population of 775,000, is equipped with two C-E Raymond Flash Drying Units, each having an evaporation rate of 12,000 pounds per hour.

The Houston Plant is typical of C-E Raymond System installations, now in service in virtually all parts of the country, meeting the varying requirements of both large and small communities. They are flexible in layout, highly efficient and thoroughly reliable; they provide for maximum utilization of waste heat.

The services of C-E specialists are available to assist you in finding the best solution to *your* sludge disposal problem. Get in touch with the office nearest to you for prompt attention.

Industrial sludges a problem?

C-E Raymond Flash Drying and Incineration Systems have been the answer for others. Write for information.

Representative list of C-E Raymond installations since 1945

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BETHLEHEM, Penna.
BLOOMSBURG, Penna.
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FOND DU LAC, Wis.
HOUSTON, Texas
LOS ANGELES, Calif.
SAN DIEGO, Calif. (Extension)
SAN FRANCISCO, Calif.
SCHENECTADY, N. Y.
SHEBOYGAN, Wis.
WATERBURY, Conn.
COLNE VALLEY, Eng.
RECIFE, Brazil
WASHINGTON, D. C.
WYOMISSING VALLEY, Penna.

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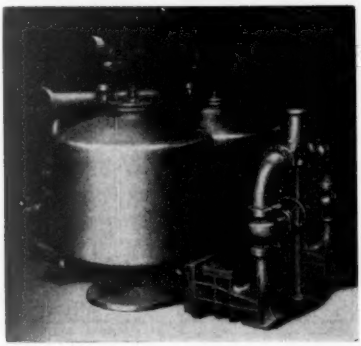

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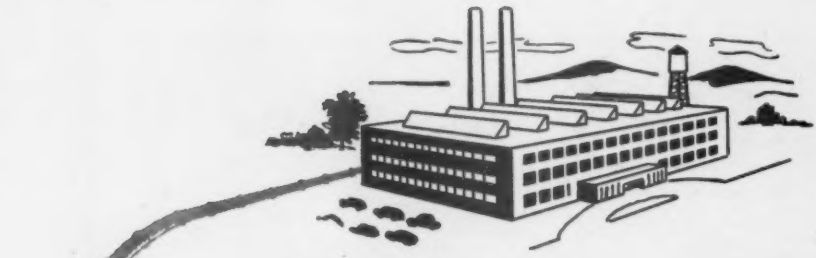

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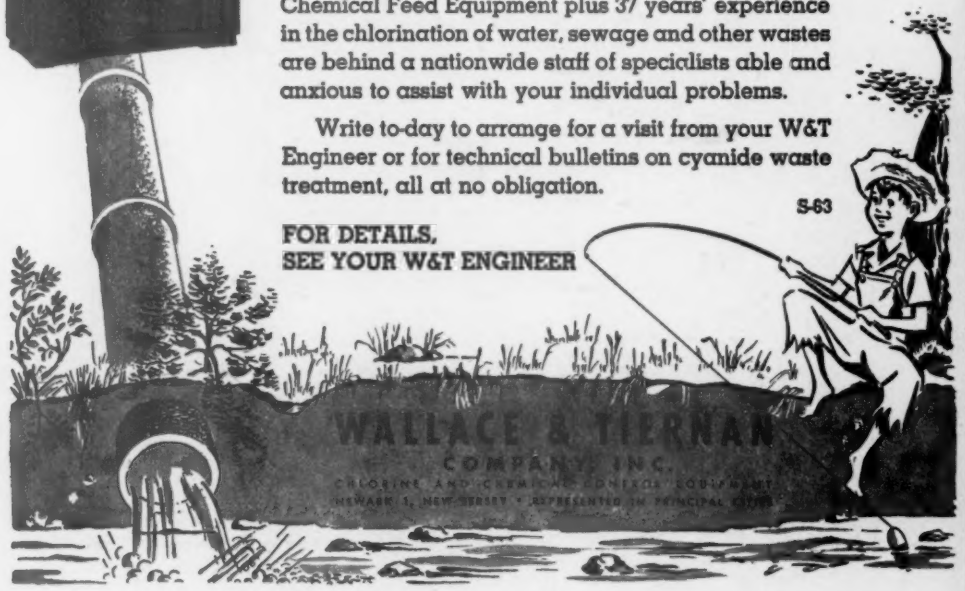
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